Joint Venture Agreement
Systems for Environmental Management

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C.L.

THE 1988 RED BENCH FIRE: DOCUMENTATION OF FIRE BEHAVIOR, FIRE WEATHER, AND THE PREBURN FUEL CONDITIONS IN THE NORTH FORK OF THE FLATHEAD RIVER VALLEY

FINAL REPORT FOR RESEARCH JOINT VENTURE AGREEMENT #INT-89439-RJVA
with SYSTEMS FOR ENVIRONMENTAL MANAGEMENT
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Mr. Jim Brown
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June 30, 1990

Dear Jim,

Enclosed is the final report for Cooperative Agreement INT-89439-RJVA "The 1988 Red Bench Fire: Documentation of Fire Behavior, Fire Weather, and the Preburn Fuel Conditions in the North Fork of the Flathead River Valley." I hope you find it interesting and informative. You might note that there are two volumes; volume one is the report while volume two contains appendices relating to more in-depth information on the climatology and Fire Danger Rating of 1988 and how it compared to the historical past from a number of stations in and near the North Fork. Also, in volume two is a chronology for events on the fire. I believe that volume one could very easily be turned into a publication that might be useful to fire behavior analysts, and managers, as well as the interested public.

Sincerely,

Charles L. Bushey

Charles L. Bushey
Research Plant Ecologist

The 1988 Red Bench Fire: Documentation of Fire Behavior, Fire Weather, and Preburn Fuel Conditions in the North Fork of the Flathead River Valley.

1990

Final Report for Cooperative Agreement No. INT-89439-RJVA

Charles L. Bushey

Systems for Environmental Management
P. O. Box 8868
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In cooperation with the
Intermountain Fire Sciences Laboratory, Missoula, MT
(USDA, Forest Service, Intermountain Research Station, Ogden, UT)

The Author

Charles L. Bushey received his B.A. in biology from Monmouth College in 1973 and his M.S. in botany from Southern Illinois University, Carbondale, in 1985. He is curently a research plant ecologist with Systems for Environmental Management and a prescribed fire specialist/fire ecologist with Montana Prescribed Fire Services, Inc., Missoula, MT. He has been the principal investigator for numerous cooperative studies on forest and sagebrush/grassland fuels, fire behavior, and vegetational response to fire. During the 1988 fire season in which the Red Bench Fire took place he operated the Regional Incident Coordinating Organization's Fire Behavior Service Center for the Northern Region of the U. S. Forest Service keeping track of fire behavior and fire weather across Northern Idaho, Montana, and the Greater Yellowstone Area. 1988 was the third severe fire season in the Northern Rocky Mountains that he has participated in the Fire Behavior Service Center (1984, 1985). He was previously employed by the Fire Effects and Use Research and Development Program at the Northern Forest Fire Laboratory (Intermountain Fire Sciences Laboratory), Missoula, MT; NALCO Environmental Sciences, Northbrook, IL; and the Lake County Forest Preserve District, Libertyville, IL.

Research Summary

Information on the developmental history of the Red Bench Fire in the North Fork of the Flathead River valley has been summarized. Evaluation of the Fire Danger rating, fuel loads and vegetation, previous fire history, and weather conditons present preceding and during the fire are discussed.

Understanding the contributing factors to a significant large wildfire incident helps natural resource managers prepare for similar events. Documentation of large fire behavior provides valuable insight in to the complex interactions between the fire and it's environment which will not only aid in possible wildfire suppression activities through increased safety, but also aid in out knowledge of the role of natural fire occurrence within wildland settings such as Parks and Wilderness Areas.

The documentation is divided in to two volumes. The first volume summarizes the Red Bench Fire and contributing factors. Volume two contains appendices which go more indepth on particular subjects such as the climatology of the region with an emphasis on the 1988 fire season, comparison of the 1988 fire season Fire Danger rating with other previous severe fire seasons, and a cholonology of particular events relating to fire behavior and fire weather on the fire incident.

Dedicated to all fire fighters who have sacrificed their lives in the preservation of our natural and man-made national resources. And especially those who died during the 1988 wildfire season in the Northern Rocky Mountains on the fires.

Cheryl Old Horn Deputee; Crow Agency, MT.
Brush Coulee Fire, August 10, 1988
Vehicle accident, first women fire fighter killed on a wildfire in the United States.

Patrick David; Coeur d' Alene Agency, ID.
Red Bench Fire, September 9, 1988
Falling tree snag.

Ed Hutton; Bureau of Land Management, Casper, WY.
Clover/Mist Fire, October 11, 1988
Falling tree snag.

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The 1988 Red Bench Fire: Documentation of Fire Behavior, Fire Weather, and Preburn Fuel Conditions in the North Fork of the Flathead River Valley.

Volume 1

INTRODUCTION

During the summer of 1988 while fire fighters were battling the many large wildfires throughout the Northern Rocky Mountains (Bushey 1989) the far northern end of the Rocky Mountains within the United States remained relatively quite. Weather conditions in the mountains to the south and out on the adjacent grasslands to the east, in most cases, had been unusually warm and dry since late winter or early spring. The North Fork of the Flathead River valley located along the western edge of Glacier National Park and the eastern edge of the Flathead National Forest in northwestern Montana was also experiencing an unusually dry summer, but temperatures were not extreme. The live and dead vegetation (fuel) through which a fire will burn gradually continued to dry as the summer progressed. By early August fuel conditions west of the Continental Divide were dry enough for lightning to start fires in the southern areas of the Flathead National Forest and within the nearby Bob Marshall Wilderness. My the middle of the month passing storms had started several high elevation fires within the Park which were being actively suppressed. The strikes from the passing storms were dutifully recorded by the Forest Service Lookout on top of Cyclone Peak, as she kept a watchful eye for new fire starts in the valley and surrounding mountains. This was her first season as a fire lookout and until now it had been relatively uneventful. As occasional smoke from a lightning strike developed it was reported, otherwise the many lightning strikes were recorded in a log as to where and when they had occurred. No one knew that one of her earlier recorded lightning strikes was a hold-over, or sleeper lightning fire. The strike had ignited accumulated, dry conifer needles and twigs and was smoldering and spreading very slowly. This fire was producing very little smoke from the smoldering in dry fuel, and this

light smoke was being filtered through the forest canopy preventing it from being visible to observers.

On the afternoon of September 6, 1988 the hold-over lightning strike within the Glacier View District of the Flathead National Forest erupted into a wind-driven project fire with the passage of a dry-cold front. The fire was initially spotted by a local logging crew and was burning intensely on a nearby ridge. While the logging crew and an aerial observer watched the fire began to move into the crowns of the surrounding forest. Very quickly the tops of the conifers became fully involved and the fire was traveling from tree to tree (a crown fire). The Red Bench Fire rapidly expanded to the east into the North Fork of the Flathead River Valley driven by winds reported by aircraft to be up to 50 MPH. Within four hours the fire was estimated to be about 700 acres in size and a potential threat to numerous residential structures in the vicinity if the winds persisted. The wind did persist and the fire was 2,027 acres by the end of the first day.

A Type 1 Team was ordered to coordinate the fire suppression activities. At the time there were only eighteen of these national teams which specialize in large, complex incidents; particularly fire incidents. A Team was located in Missoula which had just finished with another fire incident, they received an initial briefing in Missoula and were able to be at the Red Bench Fire for a midnight line officers briefing. However, fire crews and equipment were limited in availability due to an overall national shortage because of the extensive, severe 1988 wildfire season. Sufficient forces would not be available to aggressively attack the Red Bench fire until September 10th.

By the end of the 7th the fire had covered about 14,683 acres and had penetrated in to Glacier National Park approximately 6.2 miles. The strong west to northwest winds of the previous two days had first blown the fire

across the North Fork of the Flathead River. Then the winds shifted down valley (out of the north) causing the fire's southern flank to become a fire front which then bore down on and passed through the historic Polebridge Ranger Station inside the Park and the the community of Polebridge on the river outside the Park. Fifteen residential structures, five outbuildings, four vehicles, and one tractor were destroyed by the fire in Polebridge. This made the Red Bench Fire the most destructive wildland/urban interface fire to occur in Montana during the 1988 fire season (Warm Springs Creek Fire, twelve structures and one trailer destroyed [Krebs, personal communication]; Storm Creek Fire, ten cabins, five outbuildings, and one television transmitter [Bushey 1989]); Whitehall Fire , four residences, and thirty-seven outbuildings [Bushey 1989]). Historically, it was not the most destructive wildland/urban interface fire in Montana which is credited to the 1984 Hawk Creek Fire which occurred northwest of Billings in the Bull Mountains were forty-five residences and fifty-six outbuildings were destroyed (Costamagna, personal communication). The only other historical fires in western Montana which approach the The Red Bench Fire in destruction of man-made structures were the Patty Canyon Fire in 1977 (six residences, Crane et al. 1983), and the Hougton Creek Fire in 1984 (three homes, sixteen outbuildings; Costamagna, personal communication).

While snow and rain started to fall on other wildfires during the 10th and 11th of September 1988, only drizzle and higher relative humidities were recorded on the Red Bench Fire. By the 12th torching and spotting were again reported as a drying trend returned and the fire continued to burn within Glacier National Park. Winds increased on the 16th causing the fire perimeter to again expand, but sufficient moisture was received that evening to reduce

fire behavior. The fire continued to burn in remote locations into mid-October eventually attaining an approximate gross acreage of 35,240.

The Red Bench Fire event was one fire of several to become very active following the dry-cold front passage through western Montana on September 6th and 7th. Numerous fires were burning throughout Montana, Idaho, and the Yellowstone National Park area during this time (Bushey 1989). The Canyon Creek Fire in the Scapegoat Wilderness at the southern end of the Bob Marshall Wilderness complex ran for 117,330 acres out on to the plains on the 6th (Bushey 1990), Gates Park Fire in the northeast corner of the Bob Marshall Wilderness burned 13,009 acres during September 6th and 7th (Stiger 1989), and inside Yellowstone National Park the North Fork Fire ran for approximately 60,300 acres between Norris and Mammoth Hot Springs (Bushey 1989). These fires, and others, were already large in total fire perimeter acreage and had been burning for extended periods of time under active suppression strategy when the dry-cold front passed. The Red Bench Fire was the only fire run to originate from an undiscovered lighting strike (spot fire) and become a large wildfire incident. This type of natural phenomena is unusual in this geographic area, not because it does not happen, but because it happens so infrequently. Understanding the events and circumstances surrounding the Red Bench Fire aids in our understanding of the natural role of fire within Glacier National Park and adjacent wilderness and managed forest lands, as well as wind driven, crown fire behavior. Increased understanding of these types of events will better enable managers to conduct park and wilderness natural fire programs in this and other wildlands, and also provide for increased safety of fire crews on suppression duty at any wildfire location in the Northern Rocky Mountains.

In understanding these types of events it is necessary to be knowledgeable in the features which control or influence a fire's growth and behavior. These influencing features include, but are not necessarily limited to, prominent geographic features and the location of the fire in relation to those features, previous fire history, current vegetation and fuel succession conditions, and climatology of the site. These features are briefly presented within this report, and are discussed more in-depth in related appendices located in Volume 2.

General Study Area Location and Geology

The North Fork of the Flathead River Valley in northwestern Montana is a large north-northwest to south-southeast oriented valley formed from a gap which developed behind the block of Precambian rocks which slide eastward on the Lewis and Clark Overthrust. Over thousands of feet of tertiary valley fill deposited by glacial and stream action have been superficially reworked by the river. The valley bottom along the North Fork of the Flathead River drops from about 3,500 ft msl at the Polebridge Ranger Station to 3,146 ft msl at the gaging station north of the community of Columbia Falls, a distance of approximately 30 river miles. The valley bottom varies from 2 to 3 miles in width, and is relatively level, bounded on the sides by extensive moraines which provide some gentle topographic relief. The river acts as the political boundary between the Flathead National Forest and private inholdings on the west bank, and Glacier National Park to the east.

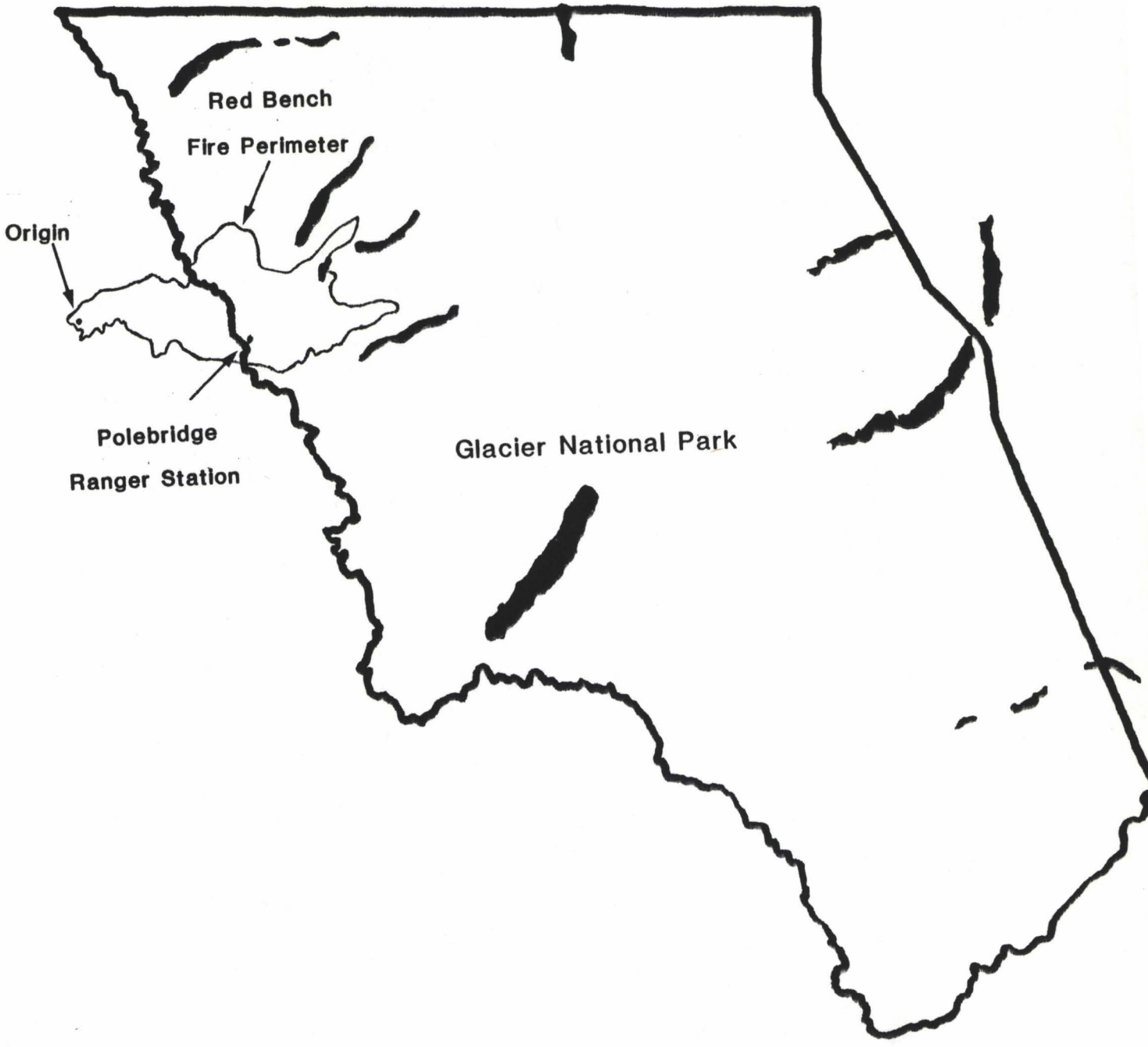
The southern end of the Whitefish Mountain Range (south of the Canadian - United States International boundary) on the Flathead National Forest side are generally rounded mountains ranging in elevation from about 4,250 (Ninemile Lookout) to 7,531 ft msl (Moose Peak). In between these peaks are well

dissected, narrow mountain valleys with the principal drainages flowing generally from west to east in to the North Fork of the Flathead River. These drainages commonly drop 3,500 ft over their 11 to 16 mile lengths.

Within Glacier National Park the Livingston Mountain Range defines the eastern edge of the watershed with craggy, glacial carved peaks ranging from about 6,800 (Dutch Ridge) to 10,100 ft msl (Kintla Peak) along the Continental Divide. Streams from the Livingston Range tend to flow from northeast to southwest, frequently with large lakes formed within the upper reaches of the glacial carved valleys behind terminal moraines acting as dams. Sides of the streams have extensive lateral moraines. Many of streams have as their source glaciers and snow fields existing above 9,000 ft msl. Drops of up to 5,500 ft over 11 to 16 mile lengths are common on the streams this side of the North Fork of the Flathead River.

The Red Bench Fire origin was in the Red Meadow Creek drainage on a north-northwest facing slope at approximately 5,650 ft msl, about 1,200 ft below the ridgetop (T35N, R22W, SW corner section 16). This origin point is approximately six miles up canyon from the Red Meadow Creek junction with the North Fork of the Flathead River. The drainage in this area is approximately west-southwest / east-northeast in orientation with the north aspect strongly influenced by winds from the west and northwest. Distances between ridgetops near the fire's origin is approximately 2.5 miles. The Polebridge Ranger Station, and the small community of Polebridge, lay about 7 miles to the east of the fire's origin site and on the banks of the river. The fire would eventually sweep through the community and penetrate another 9 miles in to the high elevation interior (about 7,700 ft msl) of Glacier National Park following the drainages of Akokala, Bowman, and Quartz Creeks (Figure 1).

Figure 1. Red Bench Fire location in respect to Glacier National Park.


Red Bench
Fire Perimeter
Origin
Polebridge
Ranger Station
Glacier National Park

Area Vegetation and Fire Groups

The valley bottom of the North Fork of the Flathead River and the lower reaches of the side drainages are densely forested with seral lodgepole pine (Pinus contorta)(Fire Group Seven; Fischer and Bradley 1987). These forests are principally below 5,000 ft msl, and are commonly less than 150 years of age (Key 1983). The stands have been frequently regenerated by fire, or by a mountain pine beetle (Dendroctonus ponderosae) / fire cycle. A few exceptions exist at this low elevation. These are either composed of Douglas-fir (Pseudotsuga menziesii) / western larch (Larix occidentalis) benchland stands between 350-500 years old often dominated by climax Douglas-fir and spruce (Picea englemannii x glauca)(Habeck and Weaver 1969)(Fire Group Six and Nine), or are relatively old (250-300 years) riparian communities dominated by spruce and black cottonwood (Populus trichocarpus)(Barrett 1983)(Fire Group Nine). Occasional small groves of aspen (Fire Group Zero) also occur, but are generally less than 100 year of age (Barrett 1983). Seral stands of ponderosa pine (Pinus ponderosa)(Fire Group Nine) occur on scattered locations throughout the valley, and have exhibited limited regeneration during this century (Lunan 1972). These sites are generally on dry benches below 4,000 ft msl where ponderosa pine seed source was available and post fire regeneration of other more mesic species was severely restricted for extended periods. These ponderosa pine populations represent a disjunct northeastern extension of the species range in the United States (Habeck 1970). There are also areas of degraded Palouse Prairie scattered along flat benches along the river, and is an unusual vegetation community type in the valley (Koterba and Habeck 1970). This sites were originally dominated by rough fescue (Festuca scabrella) and Idaho fescue (Festuca idahoensis) with scattered mountain big sagebrush (Artemsia tridentata spp. vaseyana). Isolated encroachment of lodgepole pine

and ponderosa pine has occurred on these prairie sites. Degradation of the prairie species native composition and diversity has occurred from extensive early historical grazing by livestock and the introduction of non-native species.

Upper elevation forests (greater than 5,000 ft msl) usually have as climax species either Douglas-fir, spruce, or subalpine fir and are representative of Fire Groups Five, Six, Seven, Eight, Nine, and Ten depending upon their moisture and climax species status. Groups Seven and Nine predominate in the area within the Red Bench Fire perimeter. Generally, diversity in these forest habitat are low. Most often the herbaceous strata will be classified as being dominated by dwarf huckleberry (Vaccinium caespitosum) or clintonia (Clitonia uniflora) at lower elevations, dry and mesic situations respectively; or beargrass (Xerophyllum tenax) at higher elevations.

Area Fuel Complex

Fuel is composed of accumulated dead and live biomass available for consumption by fire. Fuel is commonly divided into various strata based on location in relationship to the soil surface. Ground fuel are all combustible materials lying beneath the ground surface including deep duff, roots, rotten buried logs, peat and other woody fuel. Materials lying on, or immediately above the ground, are termed surface fuel and include; needles, duff, grass, small dead wood, downed logs, stumps, large limbs, low brush and vegetation reproduction. Fuel associated with forest canopies are called aerial fuel and contain all live or dead vegetation above the surface fuel, including tree branches and crowns, snags, moss, and high brush. The total weight of fuel within a given area is the fuel loading. Loading is usually expressed in tons per acre and typically includes surface fuel, but may also include either of

the other two fuel categories as well. For evaluating fire behavior within the aerial fuel, such as crown fire, it may be necessary to include the fuel loading from that stratum to characterize the entire total fuel load influencing the fire's behavior. Conifer needle biomass is calculated to characterize the fuel loading available for a crown fire (Rothermel in progress). Ground fuel may be used to characterize smoldering fire behavior, or evaluate long-term burn out conditions behind a fire in surface or aerial fuel.

Fuel models have been developed to simulate various surface fuel complexes. Rothermel (1972) documented thirteen fuel models which characterized the fuel descriptors necessary for the solution of the mathematical fire spread model. Of these thirteen models the NFFL models 9, 10, and 12 are commonly utilized to describe fire behavior in the forests in the vicinity of the Red Bench Fire.

NFFL Model 9 (NFDRS Model U) describes fire behavior running through surface litter, often typified by surface fire beneath the canopy of lodgepole pine. Concentrations of dead and down woody fuel will contribute to the possible torching of individual trees, spotting and crown fire. Surface fuel loads of 15 tons per acre of which about 23% is of thousand hour timelag size are used in this model (Rothermel 1972; Anderson 1982).

Forests dominated by Douglas-fir, spruce, and subalpine fir exhibit fire behavior characterized by NFFL Model 10 (NFDRS Model G). Fires in this fuel model burn in surface and ground fuel with greater fire intensity than any of the other timber oriented NFFL Fuel Models. Dead and down woody fuel categories include greater quantities of thousand hour timelag size class materials (approximately 40% of a total surface load of 30 tons per acre) resulting from forest overmaturity, advanced stages of natural succession, or

perturbation to the forest community which has created large loads of dead material on the forest floor (Rothermel 1972; Anderson 1982). Heavily managed lodgepole pine (Fire Group Seven), western larch forest stands (Fire Group Nine) on the Flathead National Forest side of the Red Bench Fire had surface fuel loads which ranged from NFFL Model 9 to NFFL Model 10, typically between 12 and 25 tons per acre (Table 1). Most of the forested area within Glacier National Park (Fire Groups Seven and Nine) had natural accumulations of surface fuels ranging between 12 to 16 tons per acre (Table 2). Torching, crowning, and spotting fire behavior are more common in this NFFL Fuel Model 10 because of the heavier loadings, leading to potential fire control difficulties (Anderson 1982).

Areas with concentrations of total surface fuel loadings up to 34 tons per acre of fuel particles less than 3 inches in size (live fuel and 1, 10 and 100 hour timelag fuel) will exhibit fire behavior typified by NFFL Model 12 (Model J)(Rothermel 1972; Anderson 1982). NFFL Model 12 is generally considered a medium slash model, but can also represent heavy, natural accumulations of dead and down woody fuel. Unmanaged forests (Fire Group Nine) on north facing aspects within the National Forest had fuel loads between 24 to 42 tons per acre, with NFFL Model 10 predominating and isolated areas more typical of NFFL Model 12. Logging units on the north facing aspects through which the Red Bench Fire spread had loadings of about 39 tons per acre (Table 3). When fires start in NFFL Fuel Model 12 they are generally sustained until either a fuel break or a significant change in fuel types is encountered. Rapidly spreading fires of high intensity can occur under dry, windy conditions (Anderson 1982).

Total fuel load of less than 3 inch particles up to approximately 58 tons per acre, and greater-than-3-inch fuel up to and exceeding 200 tons per acre typify NFFL Fuel Model 13 for heavy slash (NFDRS Model I). Within the park

boundary to the east and southeast of the Polebridge Ranger Station was an area which would have qualified as NFFL Model 12 with occasional areas of NFFL Model 13 (Fire Group Seven), with surface fuel loads visually estimated to average between 22 and 33 tons per acre and commonly as high as about 51 tons per acre. Measured fuel loads in this area reached as high as 69 tons per acre of naturally accumulated biomass, mostly in the thousand hour timelag fuel category. This area had been subjected to considerable lodgepole pine mortality from the 1926 fire which passed through the area. Since the late 1970's this same forest had undergone a severe infection of mountain pine beetle. Additional heavy mortality in the lodgepole pine forest created localized areas of "jack-strawed" dead and down lodgepole pine boles, up through which was going surviving mature pines, lodgepole pine regeneration, and in some areas saplings of spruce and subalpine fir.

Duff at the Red Bench Fire point of origin was estimated to be approximately 3 inches in depth in NFFL Fuel Model 12 (Fire Group Nine). This is the accumulated forest needles and twigs which lie above the soil surface that initially sustained the fire. Measurements of duff depth within Glacier National Park in the general vicinity of where the fire later burned varied between 0.1 and 4.4 inches; average depth in Fire Group Seven was 1.1 inches, and in Fire Group Nine 1.5 inches.

Table 1. Preburn fuel loading summary for the Red Bench Fire within the Flathead National Forest and Private Lands.

Fire Group Seven, Surface Fuel Load (photo guide appraisal).

Average 15 tons per acre
Range 12-25 tons per acre

Fire Group Nine, Surface Fuel Load (photo guide appraisal).

Average 32 tons per acre
Range 24-42 tons per acre

Fire Group Seven, Crown Fuel Load (estimated from sample stands).

"Recent Regeneration" lodgepole pine stands; average 0.14 T/AC
"Doghair" lodgepole pine stands; average 11.29 T/AC
Lodgepole pine overstory survivors from 1926 fire with lodgepole, spruce and subalpine fir understory; 3.44 T/AC

Fire Group Nine, Crown Fuel Load (estimated from sample stands).

"Recent Regeneration" Douglas-fir stands; average 0.94 T/AC
Thinned, young western larch stands; 1.12 T/AC
Thinned, young spruce stands; 4.71 T/AC
Thinned spruce stands; 0.14-2.53 T/AC, average 2.31 T/AC
Thinned western larch stands; 0.34-2.09 T/AC, average 1.12 T/AC
"Doghair" western larch stand; 2.94 T/AC
Douglas-fir/western larch overstory survivors from 1926 fire with spruce and subalpine fir understory; 1.85-15.35 T/AC, average 8.57 T/AC

Table 2. Preburn fuel loading summary for the Red Bench Fire within Glacier National Park (Kessel unpublished data, 1976; Barrett unpublished data, 1982).

Fire Group 7, Surface Fuel Load (transect measured)(N = 30), elevation 3,515-5,400 ft msl.

	Litter (T/AC)	1 Hour (T/AC)	10 Hour (T/AC)	100 Hour (T/AC)	1000 Hour (T/AC)	Total Woody and Herbaceous (T/AC)	Duff Depth (IN)
Average	1.01	0.28	0.37	1.24	9.34	11.47	1.07
Range	0.27-2.43	0.16-0.69	0.06-0.83	0.0-6.15	0.60-67.17	1.0-68.54	0.2-2.3

Fire Group 9, Surface Fuel Load (transect measured)(N = 49), elevation 3,592-6,400 ft msl.

	Litter (T/AC)	1 Hour (T/AC)	10 Hour (T/AC)	100 Hour (T/AC)	1000 Hour (T/AC)	Total Woody and Herbaceous (T/AC)	Duff Depth (IN)
Average	1.13	0.51	0.91	2.47	12.88	16.30	1.46
Range	0.03-3.66	0.09-1.62	0.0-2.86	0.0-19.9	0.0-47.10	1.62-52.58	0.1-4.4

Fire Groups 7 and 9, Surface Fuel Load (photo guide appraisal).

Average 22-33 tons/ acre
Range 3-51 tons/acre

Fire Group Seven, Crown Fuel Load (estimated from sample stands).

"Doghair" lodgepole pine stands; 7-10 T/AC, average 10 T/AC
"Mature" lodgepole pine stands; 6-9 T/AC, average 8 T/AC
"Decadent" lodgepole pine stands; 3-5 T/AC, average 3 T/AC

Fire Group Nine, Crown Fuel Load (estimated from sample stands).

Douglas-fir/western larch overstory survivors from 1926 fire with spruce and subalpine fir understory; 10-16 T/AC, average 11 T/AC
Spruce/subalpine fir forest; 9-14 T/AC, average 13 T/AC

Table 3. Preburn fuel loading summary for Unit 3 of the Red Bench Timber Sale, on the Flathead National Forest, Units 1-2 were considered similar.

0-0.25 inch diameter, 1-hour Timelag Fuel; 1.5 tons per acre
0.25-1.0 inch diameter, 10-hour Timelag Fuel; 2.5 tons per acre
1.0-3.0 inches diameter, 100-hour Timelag Fuel; 10 tons per acre
3.0≥ inches diameter, 1000-hour Timelag Fuel, 25 tons per acre
Total Dead and Down Fuel Loading; 39 tons per acre
Duff Depth; 3 inches

Area Fire History

Barrett (1983) found that the fire history of the North Fork of the Flathead River valley, and particularly the vicinity near the Polebridge Ranger Station, was "one of frequent and sometimes extensive underburns followed by occasional, severe stand-replacing fires." He concluded that large fires of 1,000 - 10,000 acres in size occurred on the average of about sixteen to twenty-three years; major fires in excess of 10,000 acres occurred on the average of about 39 years.

Barrett was able to examine approximately five hundred years of fire history, which included the last three hundred years forming a fairly complete chronology, within this study area portion of Glacier National Park and found that an apparent increase in fire frequency occurred after the mid-1800's. While some of these fires covered extensive acreage within the drainage most were principally fires which underburned the forest vegetation. He was able to map historical fire occurrence in either portions, or much of the same area as burned by the 1988 Red Bench Fire in the approximate fire years 1511 and/or 1522, 1539, 1595, 1643, 1655, 1667, 1683, 1705, 1720, 1722, 1735, 1745, 1755, 1760, 1768, 1774, 1787, 1796, 1800, 1803, 1814, 1832, 1837, 1841, 1844, 1852, 1860, 1863, 1866, 1867, 1871, 1873, 1876, 1879, 1887 and/or 1889, 1895, 1905, 1910, 1926, 1914, 1917, 1940, 1956, 1960 through the examination of stand age class and dating of fire scars. In addition to finding only scattered evidence of fire prior to 1655 (limited number of trees older than this age) he also found a marked decrease in fire occurrence after about 1930 which was attributed to an increase in fire suppression efficiency. Three large stand replacing fires swept the study area in 1655, 1667, and 1683 with areas between Numa and Quartz Ridges drained by Bowman Creek apparently being reburned each time. Much of the same area was again extensively reburned in 1889 with a fire

of lower intensity which left living but scarred trees. The next major stand replacement fires took place in 1844, 1852, 1866, 1889, 1910, and 1926 (1910 and 1926 also reburned the area between Numa and Quartz Ridges again). Fires during these later years resulted in the six major lodgepole pine age classes found in the vicinity of the Red Bench Fire, especially the years 1844, 1852, and 1926. Most areas burned previous to 1844 and subsequently reburned contain multiple age class forest canopies resulting from tree regeneration following these fires. Age classes originating from the 1844 to 1910 fires contained most of the beetle-killed lodgepole pine within the North Fork of the Flathead River drainage (Key 1983). The large stand replacement fire years after 1866 also apparently resulted in extensive acreage underburned, with stand replacement fire occurring on the steeper slopes (Barrett 1983).

On the Flathead National Forest side of the study area Barrett (1983) found evidence of thirteen fires between 1655 - 1926, of which eight also scarred trees within Glacier National Park, and five were classified as major fire years. He suggested that these fires either ignited outside the park and were wind blown in to the park, or were the results of multiple fire starts from one or more lightning storms during that fire season. He found evidence in the Fire Atlas from Glacier National Park of four fires which started on the west side of the Flathead River and crossed over to the east side between 1910 and 1926, but that no fires were mapped crossing this boundary after 1926 in the study area. It is also possible, through apparently unusual for a fire to start on the park side of the North Fork of the Flathead River and establish fire on the west side of the river. This occurred in 1967 on the Flathead Fire on Apgar and Huckleberry Mountains when the wind shifted during a frontal passage and the convection column was oriented downslope and out of the east (Bunney 1967). The Flathead National Forest Fire Atlas for the area in the

vicinity of the Red Bench Fire list 1910 and 1926 as years in which considerable acreage was burned on the Forest. A panoramic photograph taken from the Benchmark Lookout (T35N, R22W, section 20) in the 1930's looks down the South Fork and Red Meadow Creek drainages and clearly shows evidence of fires mapped as occurring in 1907, 1910, and 1926. Both 1910 and 1926 were severe fire seasons throughout Glacier National Park with 100,000 and 50,000 acres total burned within the park in each respective season.

The 1926 fire in the North Fork of the Flathead River valley started by lightning during July and was estimated to be about 10,000 acres by the 20th. The fire continued to burn until August 20th when rains arrived ending the fire between 15,000 - 20,000 acres. The area initially burned in 1926 was to the south of the Red Bench Fire but the eventual perimeter of the 1926 fire, as it burned east in to Glacier National Park and southeast through the area where the community of Polebridge is currently, is very similar to the perimeter for the Red Bench Fire. Evidently similar topographic, fuel continuity, and climatological influences affected the pattern of burning on both fires. Two other fires were also burning on the Flathead National Forest throughout the summer of 1926, one in the Middle Fork of the Flathead drainage, the other on the Talley Lake District.

Area Climatology and Fire Danger

Climate in the North Fork of the Flathead River valley is an area transistional between the moderate and moist, maritime climate influenced by air masses arriving from the Pacific Ocean and the continental climate which predominates east of the Continental Divide. Summers are generally short and moist with moderate temperatures and cool nights. July and August are the typical summer months, and are also the peak historical fire months. Autumn

(September-October) comes early and is distinctly a transistional season between summer and the very wet, cold winter months of November through March. Spring, April and June, is another transistional period with numerous cool, wet stormy periods and doesn't seem to arrive until shortly before summer. Shower activity during the spring may be almost daily and is commonly mixed with snow, especially at the higher elevations. In most years, June will be the wettest month. The broken mountainous topography supports a continumn of climatic conditions with differing combinations of altitude, slope, and aspect. Snow in the valley usually disappears between April and May, but may remain at elevation as low as 6,000 - 6,500 ft msl as late as July. Summer and Fall storms generally track from the west or southwest with the main season of thunderstorm activity between mid-May and mid-September.

The Polebridge Ranger Station within the Park is a reporting station for both the National Weather Service (NWS) and the National Fire Danger Rating System (NFDRS). There are 42 years of precipitation records (1947-1988) from the station with an average Water Year (October-September) precipitation of 22.62 inches. Historical Water Year precipitation has ranged from a low of 14.62 inches in 1977 to a high of 35.09 inches which occurred during 1971. The 1988 Water Year at Polebridge ranked as the 41st driest year out of the 42 year record with 15.00 inches. The 1988 Water Year has a calculated return frequency of approximately 20 years.

Precipitation during the prefire season (October-May) of 1988 totaled 11.01 inches and was ranked as the 40th driest prefire season at the site with a return frequency of between 5 and 10 years. March and May were the only early 1988 months which received greater than the normal monthly moisture, all other months during the prefire season period were contributing to a steadily increasing moisture deficit (NOAA 1988, NOAA 1989).

Precipitation received during the months of June-August (June included because of the apparent effect of dry weather during this month in preconditioning fuel moistures) are classified as Fire Season moisture. This season receives an average of 5.05 inches of moisture during a 43 year period (1946-1988) with extremes of 0.86 inches in 1967 (one of the more severe fire seasons in recent Glacier National Park history) and 5.28 inches during 1971. The 1988 Fire Season ranked as the 42nd driest Fire Season out of the 43 year record with only 2.36 inches of which 62% arrived during June. A return frequency of the amount of moisture received during the 1988 Fire Season was calculated to be between 20 and 100 years. Extending the fire season period through September, and the end of the Water Year, again ranked the 1988 period as one of the driest on record at Polebridge, 40th driest out of 43 seasons with 3.99 inches (return period of between 5 and 10 years). This period of time receives an average of 6.40 inches of moisture with extremes of 0.95 inches (1967) and 9.98 inches (1951). During the 1988 "Extended Fire Season" August received the least amount of precipitation (9.8% of the period total) while September received the most (40.8% of the period total). September 1988 was the first month since May to receive a greater than normal amount of monthly precipitation (NOAA 1988, NOAA 1989).

Temperatures during the historical peak fire months of July and August are the warmest of the year at the Polebridge Ranger Station. July experiences the warmest average daily maximum temperature of 79.5F, followed by August with 78.9F. These two months also have the respective warmest average daily minimum temperatures of 40.5F and 39.1F. The extreme maximum daily temperature was 103F recorded in 1960. There is a 20% probability that during the month of July a temperature greater than 94F will be achieved, and during August a temperature greater than 94F. During 1988 the NFDRS temperature data did not

establish any new records for single-day, ten-day period means, monthly period means, or extreme high/low period temperatures.

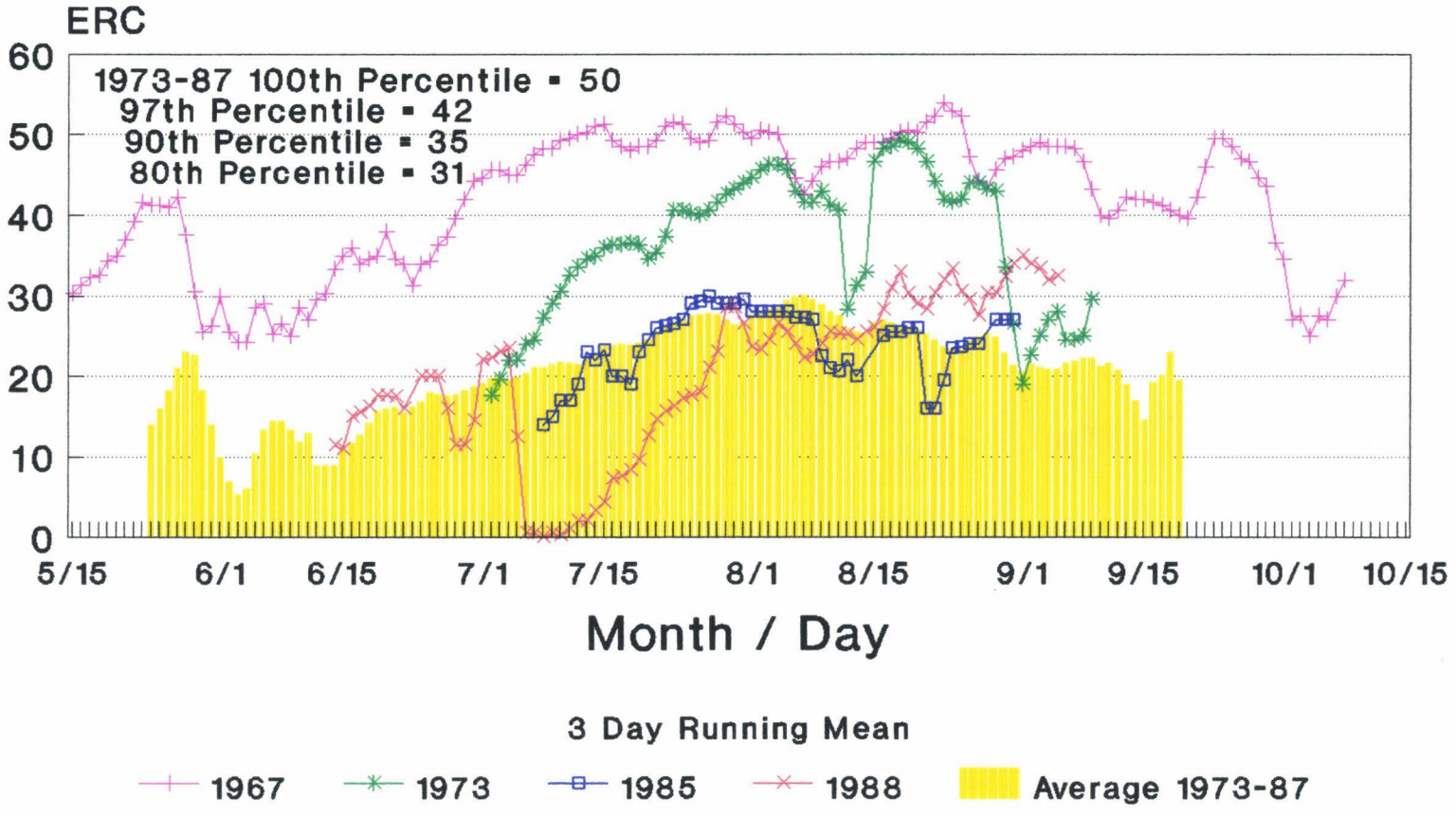
Winds during the June-September period at the Polebridge Ranger Station increase in average speed starting in June with 3.6 MPH through September with 4.8 MPH. August has the greatest variability of average wind speeds and direction. Only the months of July and August had wind speed records in excess of 24 MPH recorded from this station. All months during this period have had windy periods of up to 18 MPH. 1988 wind speeds could not be readily separated from the wind analysis.

Using the Energy Release Component (ERC) as an open-ended index of Fire Danger at the Polebridge Ranger Station shows that 1988 was not what might be termed an extreme Fire Danger season at this site. Between June 15th and the early part of July the ERC index tracked very close to the 1973-1987 seasonal average. Arrival of moisture in early July caused the index to drop down to near zero, approximately 20 points below normal for the time of season. It would take until mid-August before the index finally returned to the seasonal average. After this time the index continued to rise, being periodically set back by rising humidity and fuel moistures with frontal passages. By the time the Red Bench Fire forced the evacuation of the Polebridge Ranger Station, and the cessation of weather measurements, the index had been holding just above the 80th percentile level for seven days. Compared with the ERC index levels of the 1967 and 1973 fire seasons which climbed to the 90th percentile level or higher and were generally above the 80th percentile level for about 1.5 months, the 1988 Fire Danger measurements appear relatively insignificant (Figure 2).

Finklin (1985) evaluated the climatic characteristics of severe fire seasons in the Northern Rocky Mountains between 1910 and 1984 and classified three types of fire seasons; Early, Main, and Late. The 1988 fire season at

Figure 2. Fire Danger Rating as measured by the Energy Release Component at the Polebridge Ranger Station for the seasons 1967, 1973, 1985, and 1985 compared with the 1973-1988 seasonal average.

Energy Release Component
Polebridge Ranger Station (240210)



C. Bushey/MPFS

the Polebridge Ranger Station fits most closely with Finklin's Late Type severe fire season which typically have May-June precipitation averages about 100% of normal with maximum temperatures being normal or slightly below. The Late Type season develops as warmer, drier conditions arrive in late August or early September. This type of season was found to be only marginally "severe" in this area and of short duration with a return to cooler and wetter conditions by late September. The 1988 May-June precipitation at Polebridge Ranger Station was relatively moist, being +2.6% above normal for the two month period. All of the moisture needed to move the total above the period average was received in May with June being well below average in precipitation. July and August were much drier than normal with only 38.3% of average moisture in July and 28.6% in August, fitting the Late Type fire season pattern. May temperatures at the station were slightly below normal (-0.4F), while June temperatures were unseasonably warm (+3.0F) but not extreme. July-August temperatures were cooler than normal for this normally warm period of the year, with departures from average of -1.4F during July and -0.5F in August. However, the near normal temperatures and the dry June through mid-September period combined to produce a marginally "severe" Late Type season of short duration. Without the strong wind event occurring in association with the dry-cold front passage and driving the Red Bench Fire, the 1988 fire season in this area could have been a minor footnote in history. As predicted by Finklin (1985), a return to wetter than normal conditions developed by late September.

Investigative Procedures

During the course of this documentation numerous individuals who had participated in the Red Bench Fire Incident were interviewed concerning their observations on weather, fuel, and fire behavior conditions. This included

personnel from both the National Park Service and the National Forest Service, as well as private individuals who witnessed and photographed the event. A review of the written reports concerning various portions of the incident was also completed. Whenever possible an attempt was made to confirm observations and reports of particular events with according testimonies. Individuals involved in Fire Weather prediction and Fire Behavior Research were also involved during portions of this documentation, especially during the reconstruction of the crown fire behavior modeling.

An important aspect of the fire behavior modeling was the development of conifer crown biomass estimations for fuel during the crown fire runs. To accomplish this task it was necessary to obtain forest stand characteristics from the Flathead National Forest and Glacier National Park and to run this data through the debris prediction program (DEBMOD)(USDA 1979) to obtain estimations of crown needle biomass. On the Forest portion of the fire, forest stand characteristics were relatively easy to acquire since these areas were being managed for timber production. Within the Park data from earlier surveys as well as surveys conducted after the fire in the general vicinity provided stand composition and structure. The forest stand data was used to characterize tree growth by principal species (Figure 3) and this information was used to provide input data in to the DEBMOD program for determination of average crown biomass over similar portions of the Red Bench Fire.

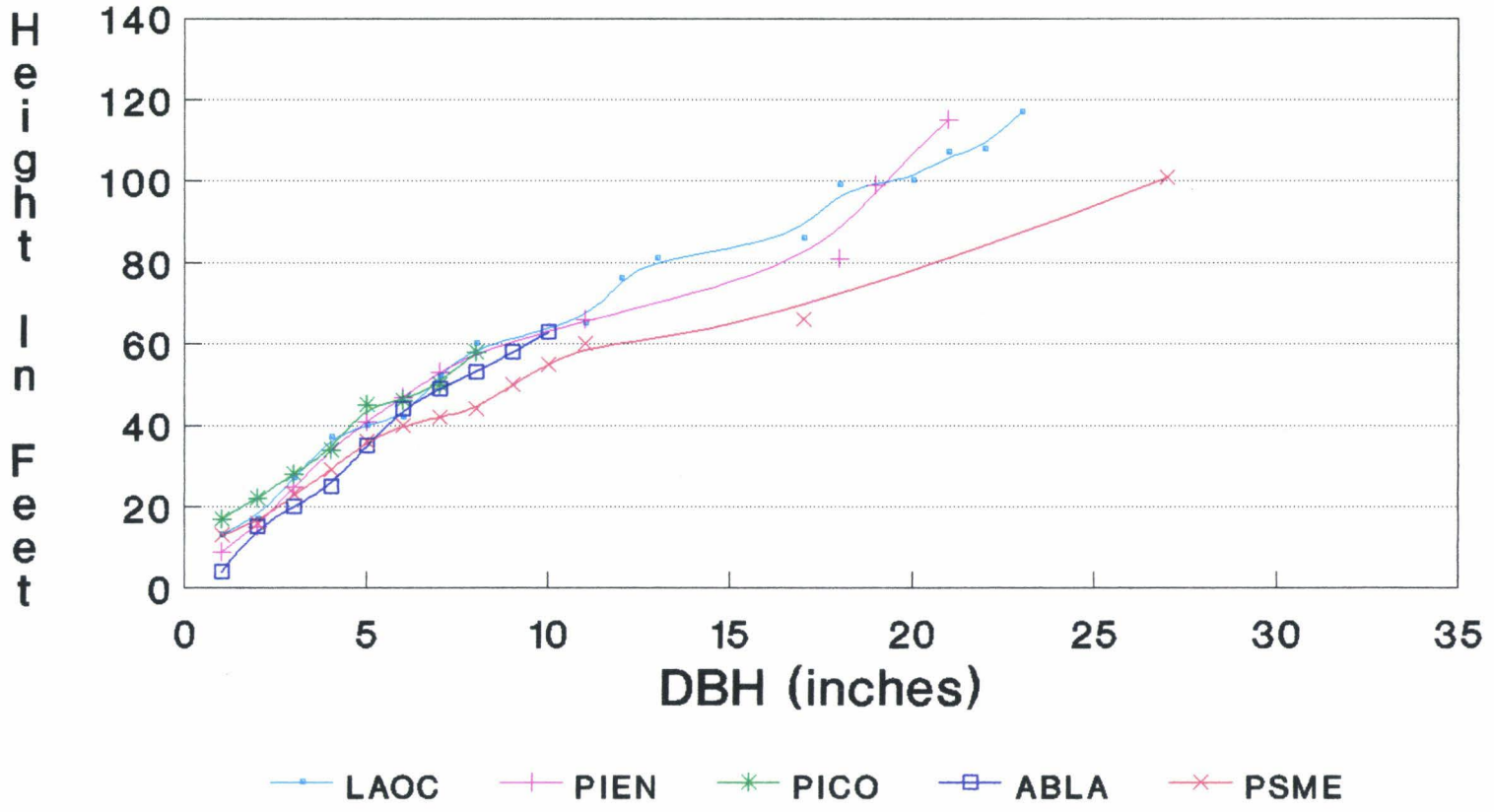
Fire behavior and fuel moisture/environmental conditions were calculated using various modules of the BEHAVE fire prediction program (Andrews 1986, Andrews and Chase 1989).

The foldout perimeter map was developed from numerous infrared imagary maps drawn during the fire as well as information from other fire perimeter maps created during or shortly after the Red Bench Fire.

Figure 3. Tree growth (height vs DBH) in the upper North Fork of the Flathead River valley in the vicintity of the Red Bench Fire.

Tree Growth

North Fork of the Flathead River



Red Bench Fire Site (1988)

The Red Bench Fire Story

During the late evening hours (2100 - 2400 hrs, all times are presented as Mountain Standard Time) of August 17, 1988 Mary Peterson in her vigil inside the lookout tower on top of Cyclone Peak was busily recording heavy lightning activity from passing storms in her vicinity. At 2300 hrs she entered in to her log a lightning ground strike at "305'02 degrees 19/37N/23W Masonry Peak area." During the next several days of observation no smoke was ever seen from this area, or for that matter the vast majority of the lightning strikes seen and recorded. Three days later, on the 20th, she noted that the lookout received 0.23 inches of rain in another thunderstorm. Heavy rain was also reported on this date in the vicinity of the lightning strike, the upper ridges along Red Meadow Creek are known for getting rain or snow every time a cloud bank passes through.

The lightning strike which Mary Peterson recorded at 2300 hrs on August 17th was the origin for what later would be called the Red Bench Fire. This lightning strike, and the fire's origin, actually occurred in the southwest corner of Section 16, T35N, R22W. This location is closer than what was estimated at the time of the strike but on the same compass line from the lookout tower as was reported in the log. There is approximately 7.5 air miles between the lookout and the fire origin. Inaccuracy in recording precise distances is a common occurrence due to darkness and the deceiving appearance of distance that often accompanies lightning strikes. Add on to this task the necessity of recording the rapidly occurring strikes during the middle of a storm with lightning occurring in nearly every direction.

The lightning strike fell in an area of subalpine forest (Fire Group Nine, NFFL Fuel Model 10, Abla/Clun habitat type, 5,650 ft msl) dominated by a dense overstory of subalpine-fir (Abies lasiocarpa) and lodgepole pine (Pinus

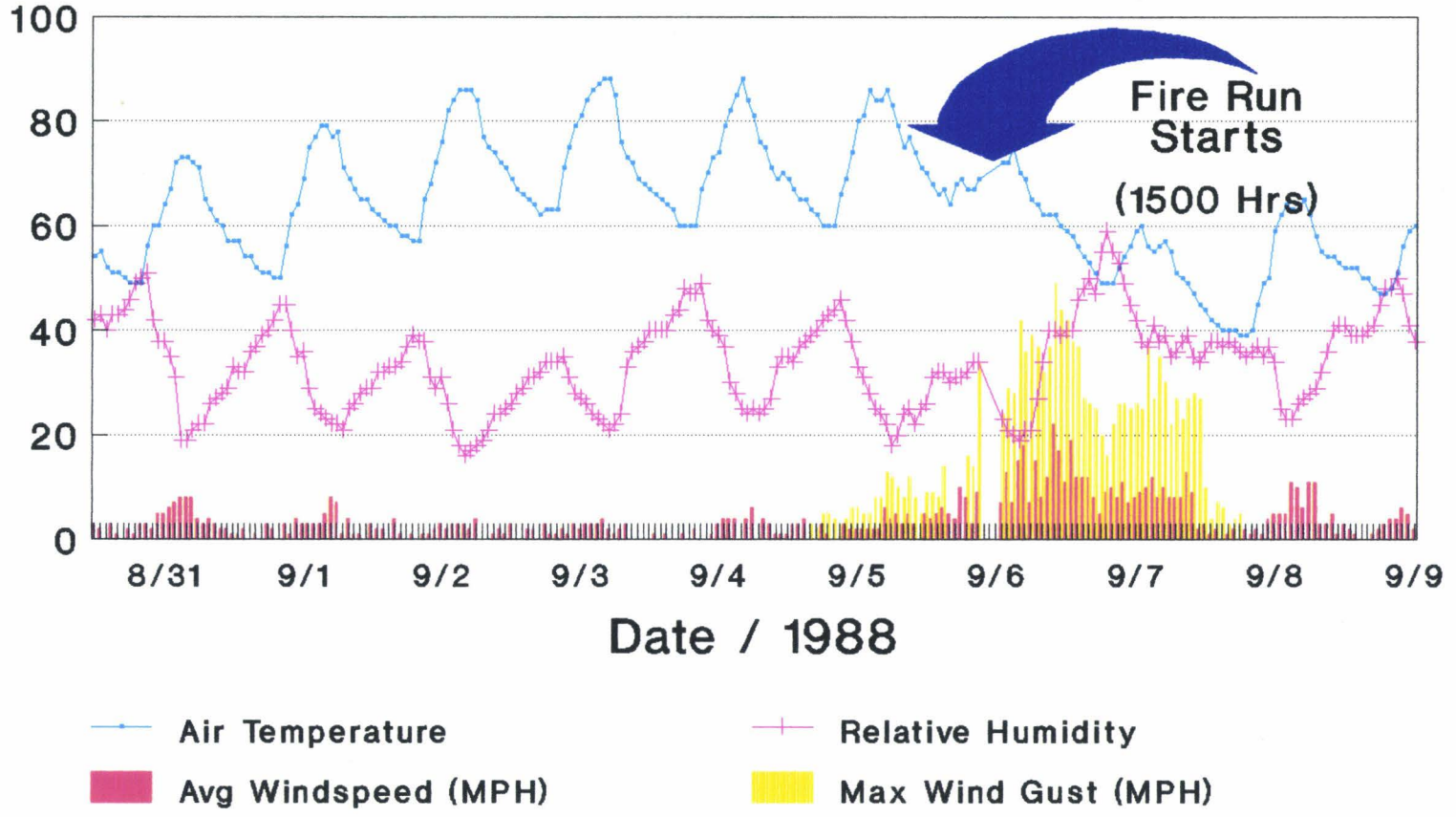
contorta) with an understory of subalpine-fir saplings and a thick growth of menziesia (Menziesia ferruginea). The site had a north-northwest aspect with 55% slope. Duff depth in the vicinity of the strike was estimated to be approximate 3 inches which the dense overstory protected from the influences of periodic rain showers, sunlight, wind, or other extreme influences of the environment allowing for the gradual drying of the fuel on the forest floor. The approximate moisture level of the upper duff layer (estimated from Thousand Hour Fuel Moisture content) would have been 16-18% providing the strike with a marginal ignition probability of a single stroke negative discharge of about 11% (Latham and Schlieter 1989). With a relatively constant microclimate under the closed tree canopy, relative humidity and fuel moisture varied little over the next 403 hours (16.8 days) before the lightning strike was discovered as a fire on September 6th.

During the nearly 19.5 days following the lightning strike weather conditions as measured at the nearby Cyclone Peak RAWS (Remote Automatic Weather Station) on Cyclone Peak (approximately 7 miles southwest, 5,312 ft msl, northeast aspect, no forest canopy) became progressively warmer and dryer. Additional moisture was recorded at Cyclone Peak RAWS on August 26th (0.12 inch) but had little impact on the overall trend. Between the time of the initial fire origin and the date when the fire was first discovered the RAWS station measured 11 days when maximum temperatures approached 80F or greater, including the final 5 days. Relative humidities during these final 5 days preceding the fire run at Cyclone Peak Raws varied between lows of about 20% during the afternoons and highs around 50% during the early morning hours. Peak afternoon RAWS average 20-ft wind speeds were generally light between 4 and 8 MPH (Figures 4 and 5). 1-hour fuel moisture varied between lows of 3-5% and high values of 8-11%, 10-hour fuel followed similar diurnal cycles with

Figure 4. Fire weather from the Cyclone Peak RAWS for the period midnight August 30th through noon September 9th; including temperature, relative humidity, average and maximum gust 20-ft wind speeds.

Fire Weather

Cyclone Lookout RAWS (3241915E)

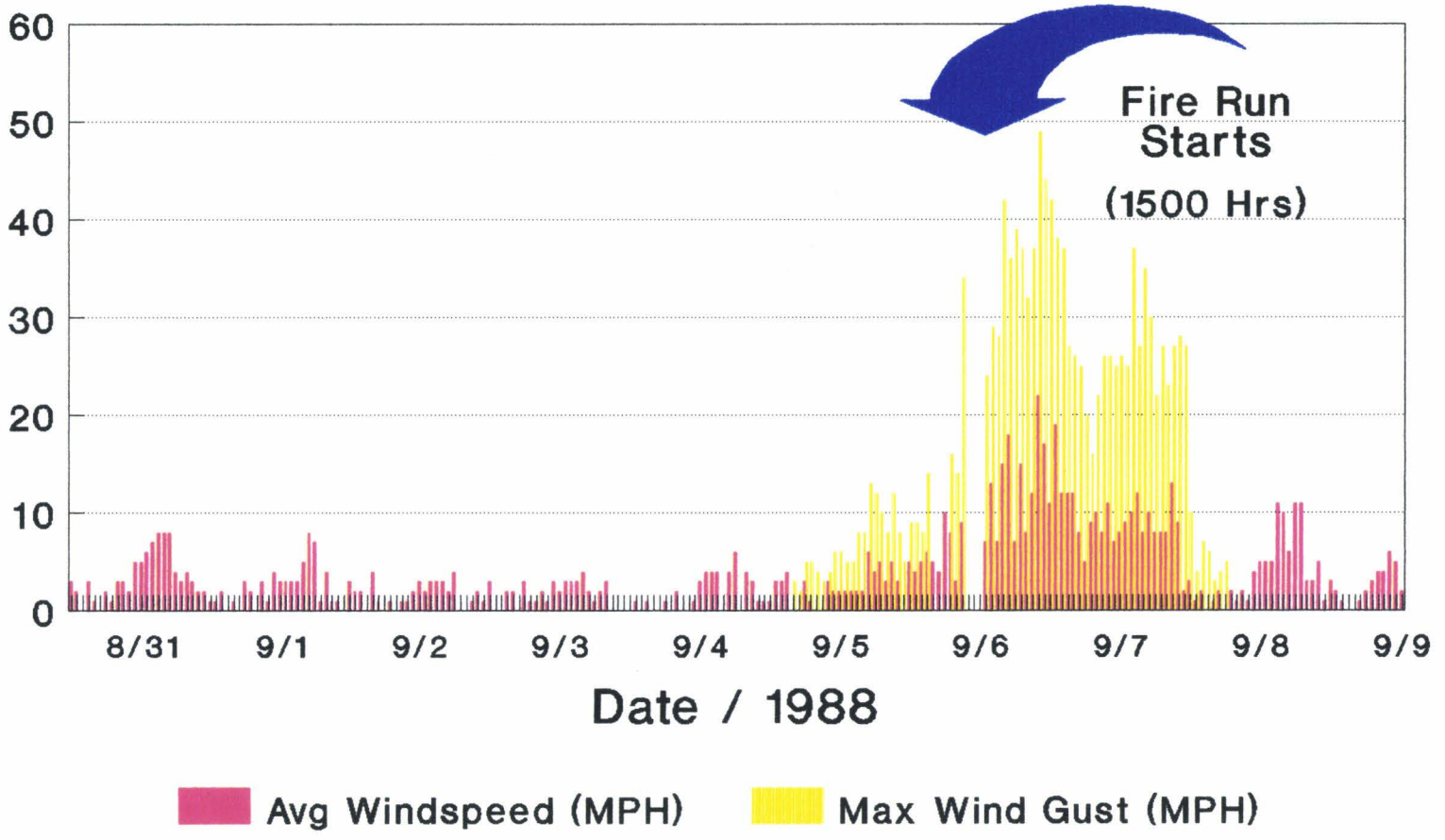


Red Bench Fire (1988)

Figure 5. Hourly average and maximum gust 20-ft wind speeds from the Cyclone Peak RAWS for the period midnight August 30th through noon September 9th (maximum gusts only recorded during September 5-8).

Fire Weather

Cyclone Lookout RAWS (3241915E)



Red Bench Fire (1988)

lows of 6-8% and morning high moisture values of 10-13% (Figure 6).

Several times during this smoldering period in the fire's growth people traveling on a logging road located about 100 yards below the lightning strike, thought they smelled "fresh" smoke in the vicinity. They would stop and visually scan the area for any sign of smoke, and not finding any would attribute the smokey ordure to drift smoke from the large Dry Fork Fire burning on the Kootenai National Forest to the west.

On Sunday afternoon, September 4th, the National Weather Service's (NWS) Fire Weather Office in Missoula issued a "Red Flag Watch" for the upcoming Monday afternoon and Tuesday. This Watch was issued because of expected strong, shifting winds which would be associated with a dry-cold front passage which was expected to push the dome of surface and upper level high pressure east and away from the northern Intermountain West. This high pressure pattern had been contributing to an extensive area of low humidities, high temperatures in the upper 80F to lower 90F range, moderate winds, and dry lightning. A strong subsidence inversion was causing the lowing of fuel moisture contents over much of the Northern Rocky Mountains with very little night time humidity recovery over much of the area. A surface thermal heat trough was ahead of the front and was causing even hotter air temperatures, in eastern Oregon and Washington States; up to 109F at Moses Lake, Washington. These warmer temperatures were expected to be in northern Idaho and western Montana on September 5th. Record and near record temperatures were already being recorded across these states and in to Montana.

The Weather Service and the Regional Incident Coordinating Organization's (RICO) Fire Behavior Service Center had been tracking the approach of the frontal passage from the Gulf of Alaska with the realization of the potential for extreme fire behavior on the wildfires in it's path. The Fire Behavior

Service Center had on September 2nd brought to the fire suppression community's attention the set of circumstances leading up to the September 1, 1967 Sundance Fire in northern Idaho which had made a 16 mile run in 9 hours with tragic results. During this same time period in 1967 major fire runs were also occurring within Glacier National Park. Many of the same set of circumstances were again occurring and communities and fire camps downwind of the many ongoing fires were being prepared for possible evacuations. Also during this time the Governor of Montana placed restrictions on all recreational activities outside community boundaries, and the upland game bird hunting season was delayed in an attempt to prevent additional new fire starts.

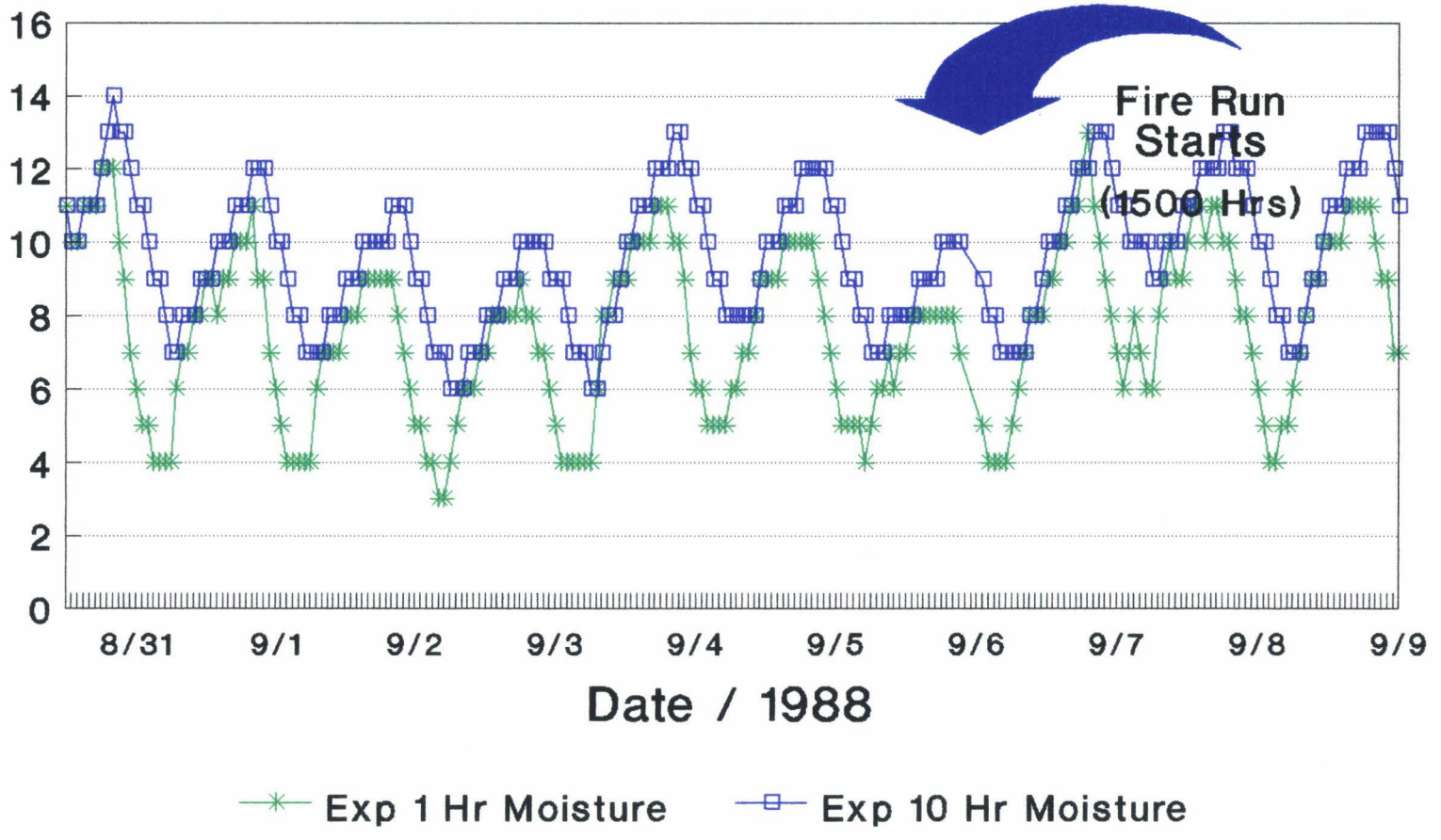
During the morning of September 5th the Fire Behavior Service Center issued a Fire Behavior Warning to ongoing fires; in conjunction with a NWS "Red Flag Watch" for strong, shifting winds associated with the expected arrival of a dry-cold front with critically dry fuels and extreme fire danger already in place. During the afternoon a special "Fire Fighter Notification of Extreme Fire Danger" was issued along with a news release of the developing situation and a Regional Fire Behavior Alert for extreme fire behavior conditions. During the evening the "Red Flag Watch" for gusty winds, low humidities, and warm temperatures was continued for western Montana and northern Idaho. A similar Watch was also issued for eastern Montana. The winds were expected to pick up during the evening as the front passed through western Montana.

The NWS changed the "Red Flag Watch" to a Warning in western Montana during the morning of September 6th with the still anticipated arrival of the frontal system. The front's position at 0900 hrs was on a line from about Bonners Ferry, ID to just west of Grangeville, ID. Winds from weather monitoring stations near the front were indicating surface wind speeds of 25 to 35 MPH similar to other dry-cold front passages during this past summer. Fire

Figure 6. 1-hour and 10-hour fuel moisture contents from the Cyclone Peak RAWS for the period midnight August 30th through noon September 9th.

Fire Weather

Cyclone Lookout RAWS (3241915E)



Red Bench Fire (1988)

lookouts on the Kootenai National Forest reported morning wind speeds of 35 MPH out of the southwest while calm conditions prevailed at the lower elevations. By 1200 hrs the front was on a line from west of Kalispell, MT to just east of Grangeville, ID and approaching the North Fork of the Flathead River valley. The Cyclone Peak RAWS started to measure slightly increasing 20-ft wind speeds about 0700 hrs averaging 8 MPH with peak gusts of 16 MPH. By about 1600 hrs average wind speeds at this station had increased to 15 MPH with maximum gusts in the upper-30 MPH range. Approximately 70 miles to the southeast along the edge of the Bob Marshall Wilderness another RAWS placed at a higher elevation (7,225 ft msl) at the Spotted Bear Lookout was obtaining better measurements of free air movement relatively unencumbered by the effects of terrain and surface vegetation. The Spotted Bear Lookout RAWS 20-ft wind speeds had started to rise shortly after midnight and by 1300 hrs were averaging over 20 MPH out of the southwest with maximum gusts of 48 MPH. Average wind speeds at this high elevation station would remain 19 MPH or greater for the next 33 hours reaching maximum gusts measured at 59 MPH mostly out of the west-southwest (Figures 7 and 8).

Night time fuel moisture recovery as measured by the Cyclone Peak RAWS the morning of September 6th were the lowest measured in several nights, with 1-hour fuel moisture peaking at 8% after a previous afternoon low of 4%, and 10-Hour fuel moisture only obtaining a maximum of 10% after rising from 7%. By 1400 hrs on the 6th the 1-hour fuel moisture would again reach its low level of 4% while the 10-hour fuel moisture level would continue to drop until finally stabilizing at 7% by 1600 hrs. Temperature, relative humidity, and wind direction measurements indicate that the front probably passed the Cyclone Peak area between 1500 - 1600 hrs. By 1800 hrs the 1-hour fuel moisture levels were again beginning to climb under the influence of rising relative humidity.

The estimated smoldering combustion average rate-of-spread (ROS) from a single source in duff is approximately 1.2 inches per hour (Frandsen, personal communications). During the 403 hours following ignition by the lightning strike, smoldering combustion would have had the opportunity to travel a circular radius of 47.3 feet with an area of 7,027 square feet (16.1% of an acre). However spread would have been elongated into an ellipse of approximately the same area by local slope and subcanopy winds. The approaching dry-cold front contributed increased wind turbulence beneath the forest canopy causing the smoldering duff to develop in to flaming combustion. Calculated fuel moisture content for the small diameter woody (1-hour Timelag Fuel) fuel in the vicinity of the origin during the afternoon of the 6th of September was 7.4% (after only attaining a peak value of about 8.4% earlier in the morning) with a Probability of Ignition of spot fires of 40%. These fuel moisture conditions were quite dry enough to carry a fire, the size of the fire would depend upon the strength and duration of any available wind. Ground fuel level wind speeds were calculated to increase from about 0.1 MPH at midnight to 4.0 MPH by mid-afternoon of the 6th. As the subcanopy wind became stronger the flame length and rate-of-spread increased allowing the fire to reach additional dead and down woody fuel around the circumference of the burned out ground fuel allowing the fire to carry into the lower branches of small trees. These small conifer seedlings and saplings in turn carried the flames even higher in to the forest canopy acting as a ladder for the fire to the taller trees.

A private logging crew which had been working further up the Red Meadow Creek drainage, under restricted hours and work conditions because of the extreme fire danger across the entire region, were driving their trucks down from the units they had been working in. They detected the first sign of the developing fire about 1400 hrs. The fire was reported at less than 0.25 acre

Figure 7. Fire weather from the Spotted Bear Lookout RAWS for the period midnight September 5th through noon September 10th.

Fire Weather

Spotted Bear Lookout RAWS (3248D408)

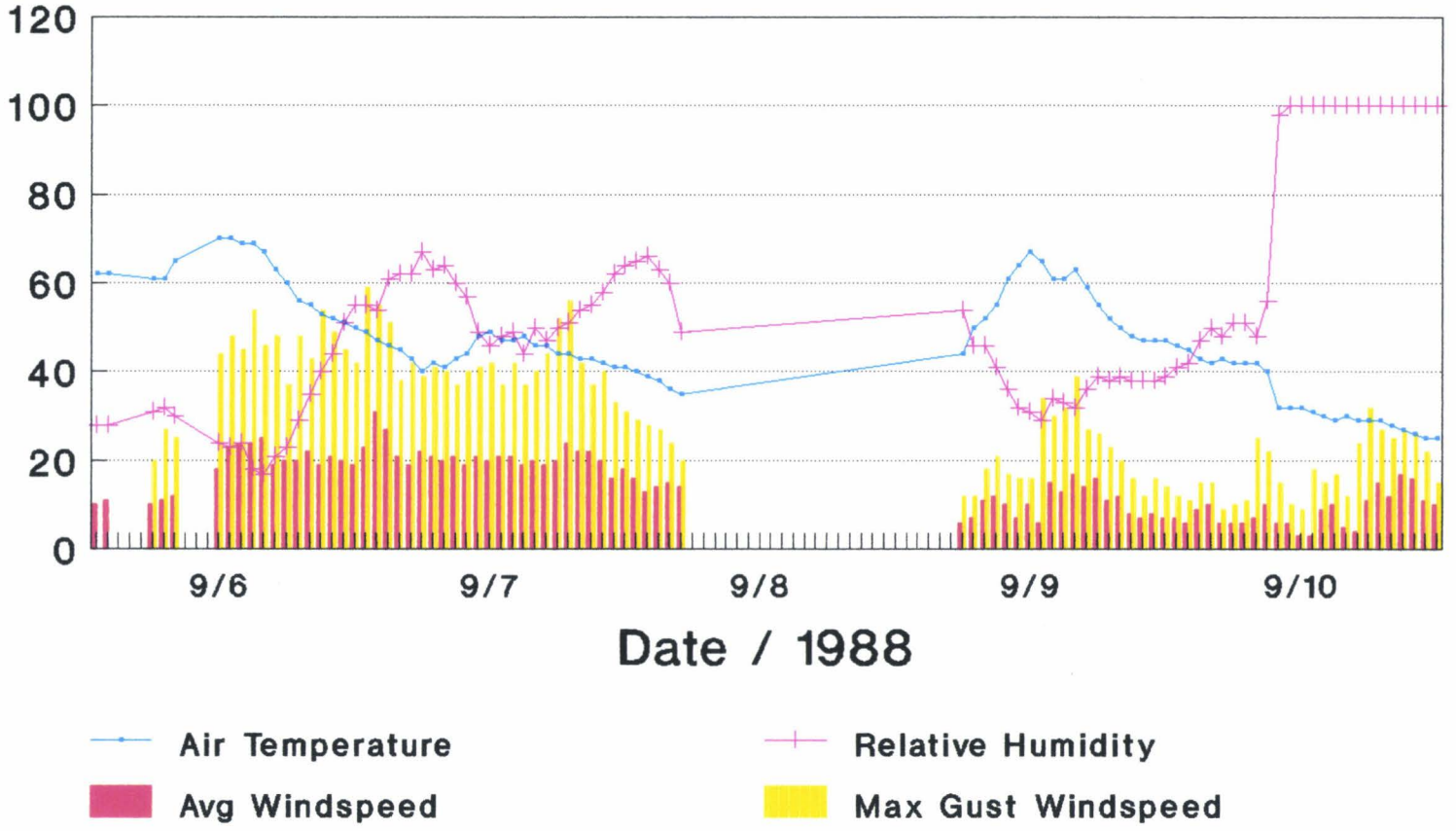
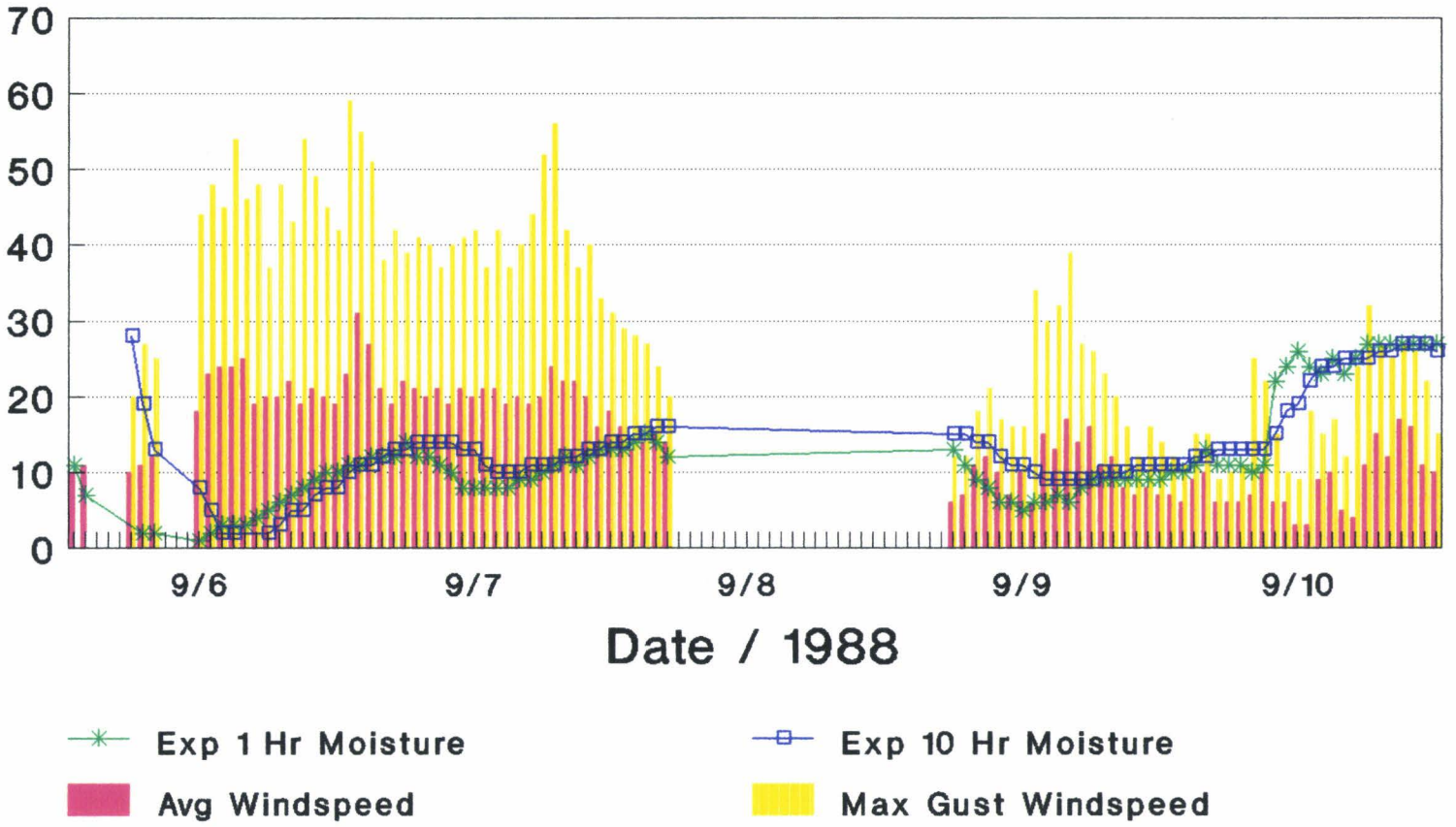


Figure 8. Average and maximum gust 20-ft wind speeds and 1-hour, 10-hour fuel moisture contents from the Spotted Bear Lookout RAWS for the period midnight September 5th through noonSeptember 10th.

Fire Weather

Spotted Bear Lookout RAWS (3248D408)



and actively burning about 200 feet upslope from the logging road. Below the road were three previously cut and unburned units from the Red Bench Timber Sale. The logging crew immediately tried to contain the fire with 16 men and three crawler tractors. They cut a fireline up the west slope and stretched 200 feet of hose which just reached the bottom portion of the fire. The crew leader scouted the ridge at 1500 hrs and determined the fire was growing to rapidly and pulled his crew back for their safety. They then built another fireline approximately 30 feet above the road to contain downslope spread.

After receiving the initial fire report from the logging crew the Glacier View Ranger District notified the Flathead National Forest Fire Dispatch Office (1425 hrs) of the incident and requested aerial reconnaissance. The Forest Dispatch radioed Cyclone Peak Lookout to confirm the smoke over Red Meadow Creek, but the poor 1 mile visibility reported at 1340 hrs had not improved and the reported fire was not visible. Thick smoke from the Dry Fork Fire to the west had restricted visibility at the Cyclone Peak Lookout for the previous 3 days. Air patrol 6HA was directed to the reported incident. At 1440 hrs the aerial reconnaissance was airborne.

At 1453 hrs the aerial observer approached the fire and reported the smoke column was not well developed, smoke was light and whispy and fire spread did not appear to be influenced by the strong winds which were blowing from the west at an estimated 30 MPH. The observer established that the fire was about 0.25 acre in size and about 130 feet above the logging road. No fire had become established in the forest canopy. Within minutes after the aircraft's arrival the first trees began to torch (Figure 9). Once torching was initiated the fire came under the influence of the west wind and in short order spotting controlled the advance of the fire. At 1505 hrs the aerial observer noted that the fire was "rolling" and any fire fighting crews approaching the area should

use extreme caution to avoid being trapped downwind. From the aircraft it was observed that after the fire started to crown there was what was described as an almost "instantaneous flashover" over the first small ridge that the fire crossed. Very quickly (calculated to be about 12 minutes) the fire became shaped like a rolling basketball of fire approximately 0.25 mile wide (ROS 0.2 MPH) and appeared to bounce and pulse as it traveled over the landscape pushed by the wind (Figure 10). After crowning the fire ran the first mile in approximately 1 hour (Figure 11). During the first 20 minutes the fire did not spot below the logging road. At 1605 hrs the aerial observer reported the fire to be on both sides of the logging road and that logging unit #2 was involved. Spread in the cutting units below the main fire was characterized by a slow moving backing fire moving down slope at an estimated rate of about 80 feet per hour. The fire then hooked to the east and burned rapidly through logging unit #1 in to Section 15. Above the fire, spread was more rapid as the flaming flanks took advantage of heavy standing dead fuel and upslope conditions. The rear of the fire did not spread back more than about 65 feet in to the westerly winds. At 1610 hrs the aerial observer estimated that the fire size was 40 acres and that spotting was occurring. Calculated maximum spotting distance at this time was approximately 0.4 miles under average 20-ft wind speeds of 18 MPH, 1.2 miles under maximum gusts 20-ft wind speeds of 42 MPH. However there was likely considerable short-distance spotting occurring down slope of the fire run not visible to the aerial observer from firebrands caught in the spiraling convection column. These spot fires "seeded" the lower slope and contributed to later spread through Logging Unit #2 as well as additional fire runs up slope and to the east which merged with the initial fire run.

The first aerial retardant drop on the fire took place at 1620 hrs and the "rough air" caused irregular dispersal. Ten minutes later the Glacier View

Figure 9. Photograph from aerial reconnaissance 6HA as the Red Bench Fire first started to have ladder fuel burn and cause isolated torching. The logging road is visible beneath the fire and Red Bench Timber Sale Unit #1 can be seen below the road. Approximate time 1500 hrs.

Figure 10. Early fire perimeter growth of the Red Bench Fire on September 6, 1988. Perimeter growth from 1605 hrs on includes area with spot fires.

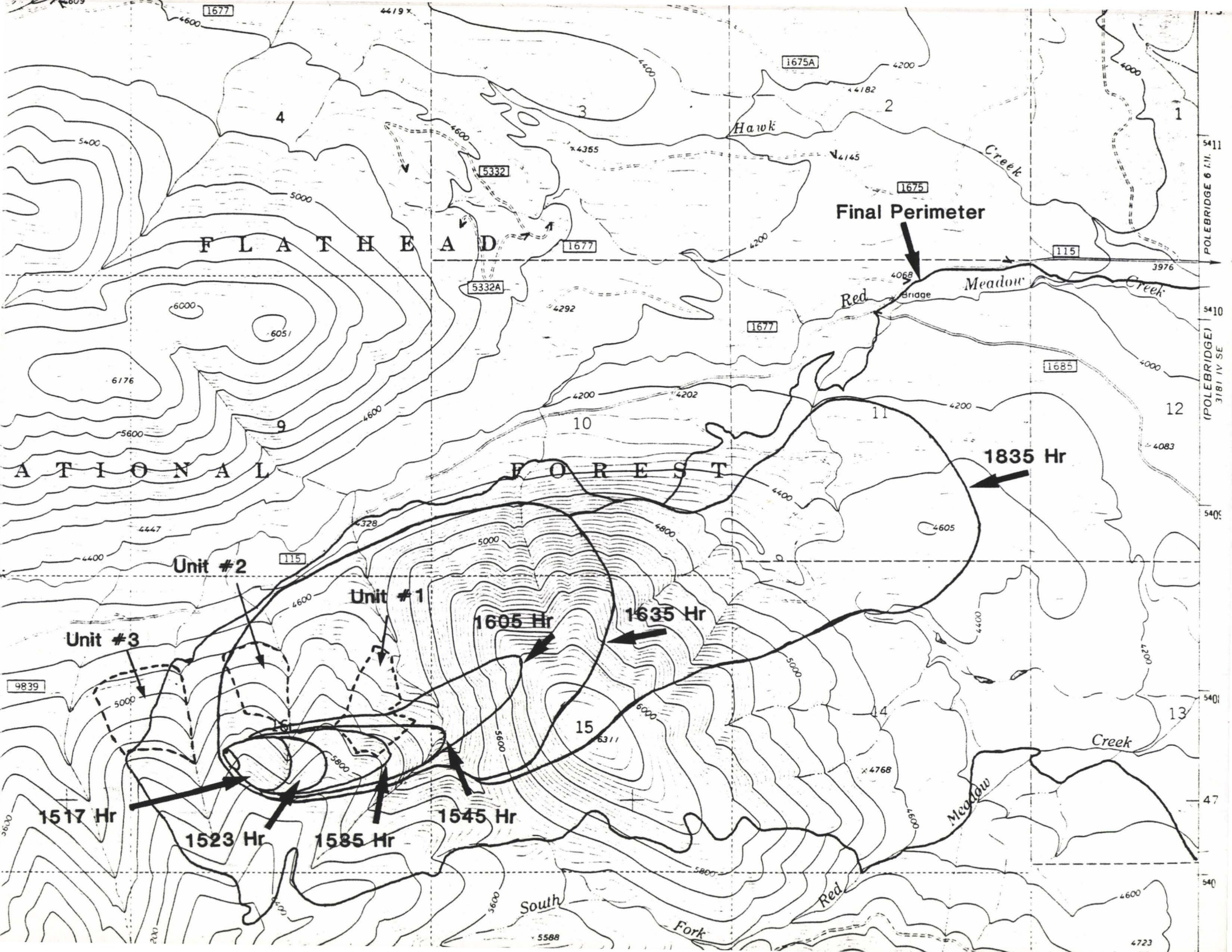
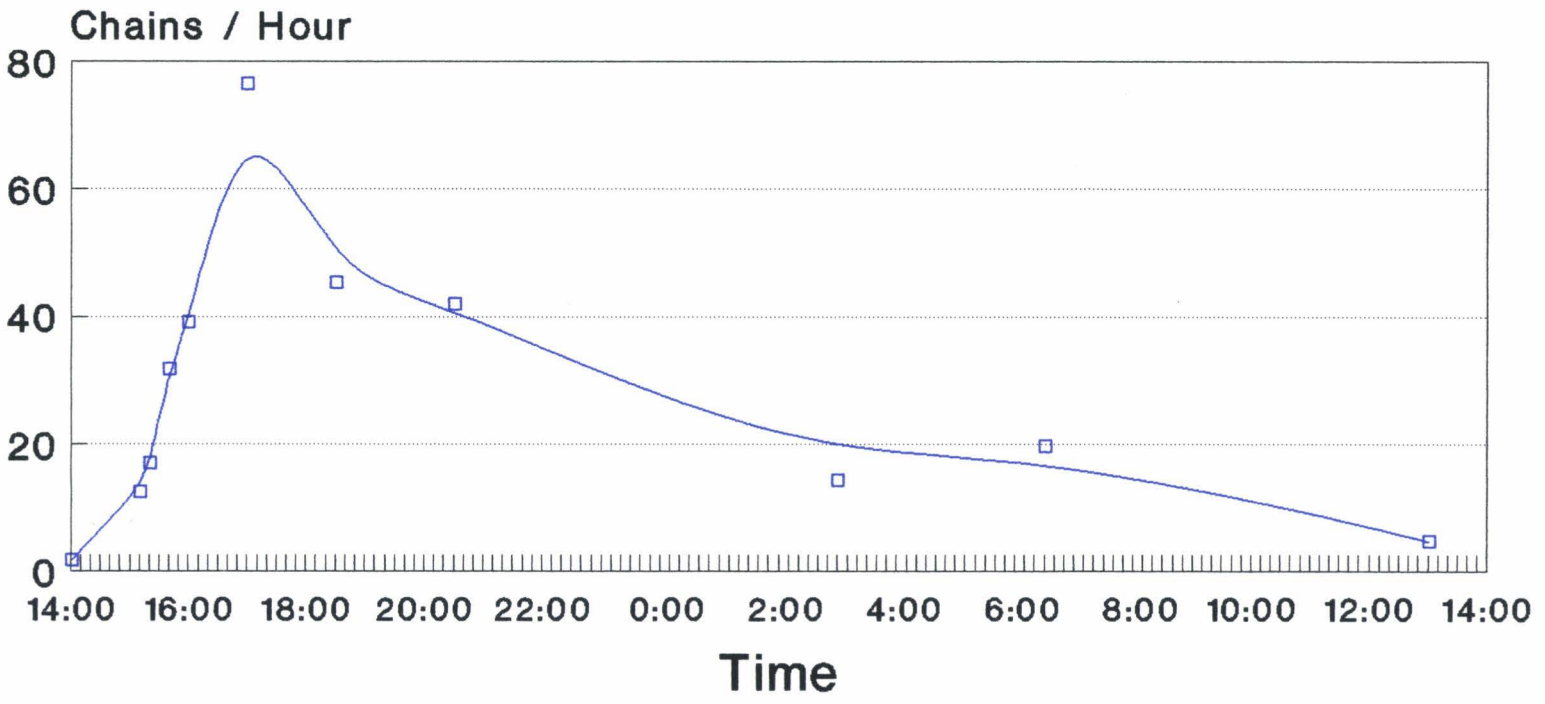

Final Perimeter
1835 Hr
1635 Hr
1605 Hr
Unit #1
Unit #2
Unit #3
1517 Hr
1523 Hr
1585 Hr
1545 Hr
FLATHEAD
NATIONAL FOREST
Hawk Creek
Red Meadow Creek
South Fork
Red Meadow Creek
Bridge
1675A
1675
1677
1685
5332
5332A
115
9839
(POLEBRIDGE) 3181 IV SE
POLEBRIDGE 6 I.N.E.

Figure 11. Red Bench Fire forward rate-of-spread from discovery on September 6th at 1400 hrs until 1300 hrs the afternoon of September 7th. The rapid increase followed by a gradual but steady decline in rate-of-spread is probably a typical rate-of-spread curve for a wind driven fire.

Red Bench Fire
Forward Rate-of-Spread



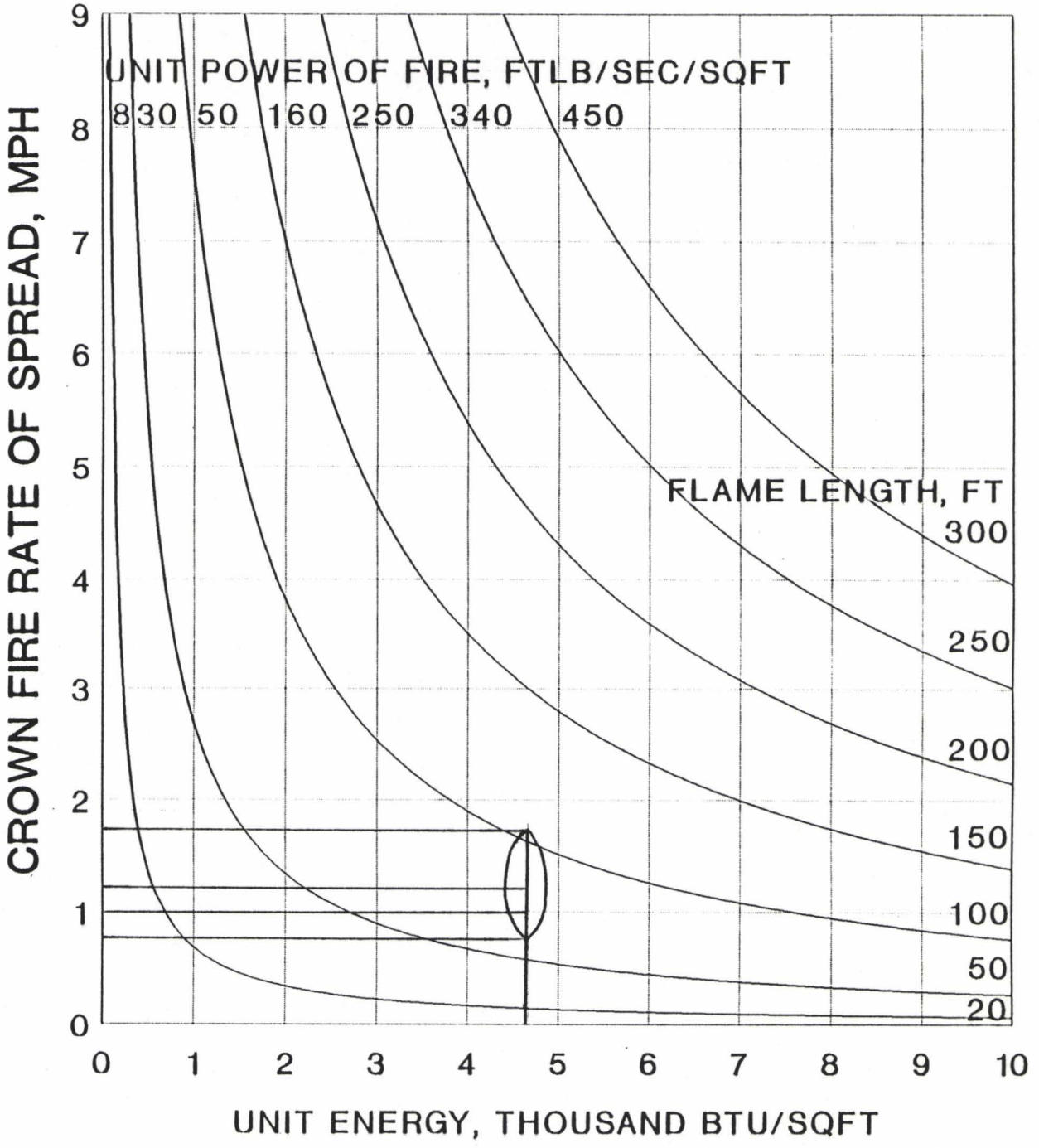
Red Bench Fire (1988)

Ranger District Safety Officer was directed to go to the Polebridge General Store to inform residents of the current fire situation and suppression actions. By 1640 hrs the fire was estimated to be 1.75 miles long (calculated to be 1.4 miles in length, ROS 0.9 MPH) and 0.25 mile wide. Using the crown biomass estimate of about 8.6 tons per acre with an NFFL Fuel Model 10 surface loading, a wind speed of 20 MPH on the forest canopy would be calculated to have created an average rate-of-spread of approximately 1 MPH (75% confidence level range 0.8-1.3 MPH, near maximum ROS 1.75 MPH)(Rothermel in progress). Above crown flame lengths of this fire would range between 60-100 feet, and the fire would vary between being wind driven (Pw) or fire driven (Pf) based on the wind speed (Pf/Pw=.8-1.3)(Figure 12)(Rothermel in progress). Cyclone Peak RAWS was measuring an average 20-ft wind speed of 18 MPH, maximum gusts to 36 MPH. The air tankers trying to deliver the retardant were experiencing 2,000 feet per minute drift because of the wind which was evidently much greater further above the forest canopy. The tankers were having no success in trying to hold the southwest flank of the fire, and threw their last loads and headed back toward Kalispell airport. A helicopter accompanying the tankers to Kalispell reported 50 MPH headwinds.

At 1730 hrs the fire was experiencing long distance spotting estimated to be 1.5 miles ahead of the main fire front and across Spruce Creek Road (approximately 3.2 miles east of the fire origin). A 20-ft wind speed of approximately 55 MPH would be needed to carry fire brands this distance. These thrown fire brands would ignite within a few moments of landing and immediately climb in to the trees. Mostly small branch material up to 4 inches in length and 0.25 inch in diameter were being carried at this time and causing the spot fires. By 1759 hrs the main fire had jumped Spruce Creek Road. The estimated fire size at this time was 700 acres and growing fast.

At approximately 1830 hrs the fire front became visible to the Cyclone Peak Lookout as it moved out from behind the ridge and on to the relatively flat bench of the North Fork of the Flathead River. The lookout described the fire "front" as initially wind driven flames traveling through the top 33% of the tree canopy. Flames were estimated to be up to 500 feet in length (not height, and included areas of exploding gases) based on the heights of local trees, and angled at approximately 35-40 degrees. This front was a deep orange in color mixed with thick black smoke. This area was highly visible from the Cyclone Peak Lookout since she was essentially above and slightly behind the flaming front and the wind was pushing the smoke ahead of the fire. As this fire front moved through the tree tops, the tops of dead lodgepole pine (the clusters of pine cones were visible against the orange background) were broken off. These 8-10 foot flying, flaming "Christmas trees" pieces could be see spiralling in to the convection column and then dropping to the ground between 0.25 and 0.75 miles ahead of the main tree top fire front (calculated maximum spotting distance 0.4 miles under 15 MPH average wind speeds and 1.0 miles under measured 37 MPH maximum gust wind speed). As these broken tree tops crashed to the ground the surrounding vegetation burst in to flame. These new spot fires quickly crowned and became tear shaped fires moving ahead of the main crown fire front. For 15 to 20 minutes the remaining crowns of the forest canopy burned with a deep red color in a mass fire situation behind the the initial crown fire front. A distinct ground fire front followed the crown fire front moving through the ground fuel up to 15 to 30 minutes after the tree top crown fire front had initially arrived at the same location. At the same time that the Cyclone Peak Lookout was making these observations the Flathead National Forest Dispatch Office requested a general public message be broadcast over the public radio stations regarding Red Meadow Creek evacuation. The request was

Figure 12. Fire behavior characteristics chart for the initial crown fire run of the Red Bench Fire, 1505 - 1605 hrs. Input included crown biomass of 8.6 T/AC, Fuel Model 10 surface fuel, 20 MPH wind speed. Horizontal lines from top to bottom represent 1) near maximum rate-of-spread, 2) upper 75% confidence level rate-of-spread, 3) average rate-of-spread, and 4) lower 75% confidence level rate-of-spread. Ellipse represents the calculated range of fire behavior.


CROWN FIRE RATE OF SPREAD, MPH
UNIT ENERGY, THOUSAND BTU/SQFT
UNIT POWER OF FIRE, FTLB/SEC/SQFT
830 50 160 250 340 450
FLAME LENGTH, FT
300
250
200
150
100
50
20
0
1
2
3
4
5
6
7
8
9
10

immediately okayed by the Sheriff's Office and the Glacier View District Ranger. The County Disaster Coordinator was informed of the decision.

At 1830 hrs the RICO Fire Behavior Service Center issued a "Special Fire Behavior Warning" based on analysis of the 1800 hrs Spokane, Washington radiosonde data. A low level jet-point was indicated by the data causing a Type 2-b wind profile with a reverse wind profile (Figure 13). Where, or even if this jet-point might affect an ongoing fire was unknown but the Type 2-b profile was known as potentially very dangerous, especially during late afternoons and evenings in rolling or mountainous terrain. Fire behavior with this type of wind profile is dominated by the wind. Being down wind of fires burning in heavy, dry fuel under these wind profile conditions could be very dangerous. The Type 2-b wind profile was likely present during some historic large fire events (Bryam 1954). Indications from the radiosonde were that the jet-point was at an elevation to possible interact with fires between 4,000 and 8,000 ft msl. All Forest Dispatch Offices and Fire Camps connected to the Forest Service electronic mail system were issued the warning, this electronic message was followed up by personal telephone calls to all Dispatch Offices in northern Idaho and northwestern Montana. The radiosonde for the same time period from Great Falls, MT showed a Type 4-a profile, a more normal wind profile with some strong winds (Figure 14). The lower elevations of the Great Falls radiosonde were being influenced by the presence of the Northern Rocky Mountains to the west with the wind speeds out of the west increasing above the mountains wind shadow effect. The primary effects of this low level jet-point would be experienced further south on the Canyon Creek Fire burning within the Scapegoat Wilderness portion of the Bob Marshall Wilderness Complex where short-term crown fire ROS of up to 9 MPH would be measured (Bushey 1990). The strong gradient winds associated with the frontal passage and possibly some

influence by the nearby jet-stream were contributing to the crown fire run on the Red Bench Fire.

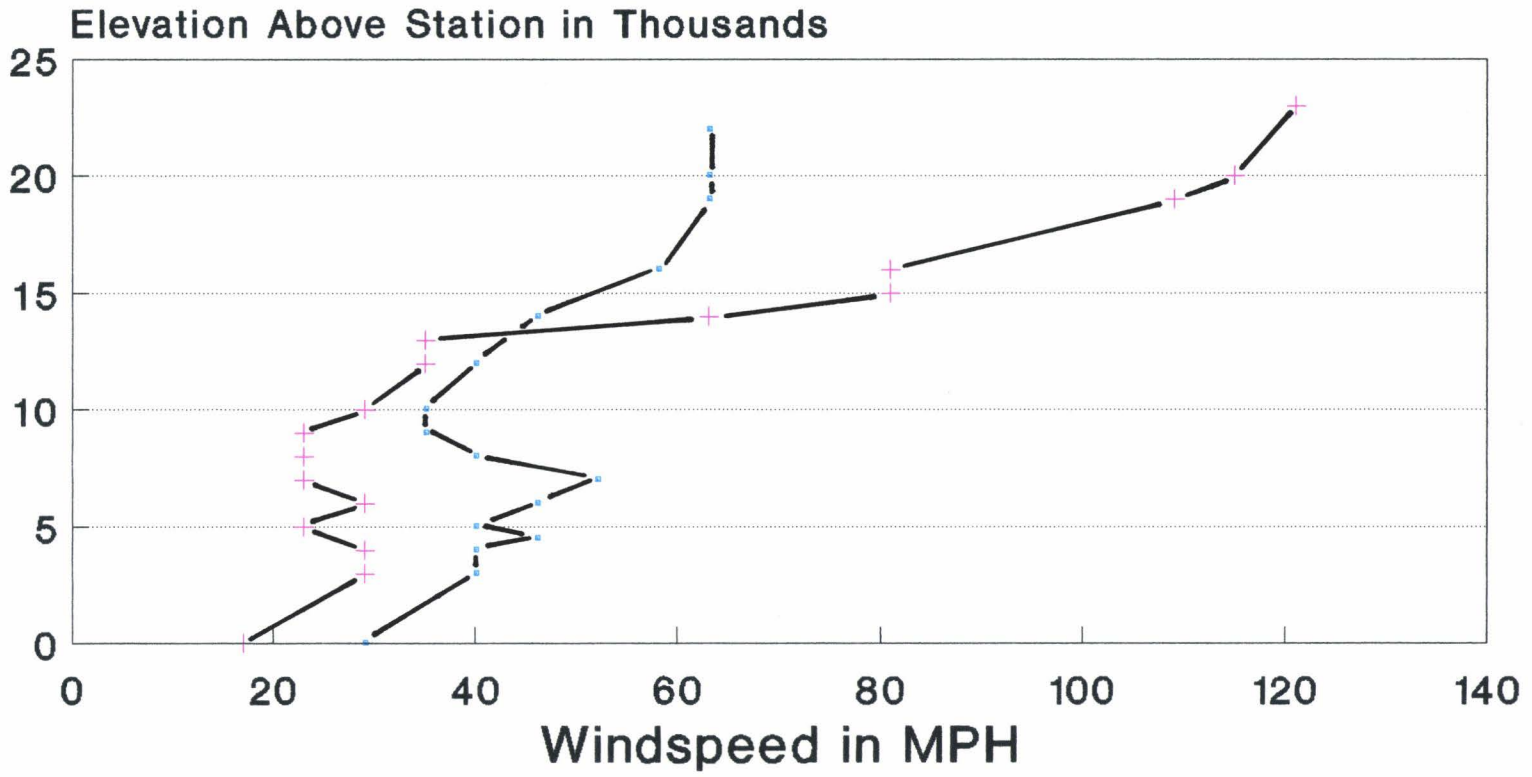
Strong winds along the exposed ridge on which the fire had been spreading were causing significant spotting problems with spot fires growing rapidly. Calculated 1-hour fuel moisture content at 4,300 ft msl beneath a managed forest stand (thinned, 200-300 stems/acre, stands of larch and/or lodgepole pine which had originated after the 1926 fire) west of Spruce Creek Road ranged from 6.6% to 7.3% between 1200 - 2100 hrs. Probability of Ignition of spot fires during this period declined from 50% to 40%. Fuel level temperatures dropped from 76F to 66F. The fire burned through this particular location at 1900 hrs.

By 1920 hrs a cat line has been started in an area west of Spruce Creek Road still not broached by the fire. This line was supported by 2 engines and 3 crews. Also at this time Red Meadow Creek evacuation procedures had begun and traffic was blocked into the area.

The constructed fireline by the cat was blown over by the fire about 2030 hrs. The fire at this time was about 3.4 miles long, 1 mile wide including areas of spot fires, and had backed about 80 feet to the west (see foldout map). During the previous 5.5 hours since the crown fire run had begun the fire had an average ROS of 0.6 MPH. Again using the average crown biomass of 8.6 tons per acre this rate-of-spread could be calculated to be maintained with a wind speed of about 15 MPH, Cyclone Peak RAWS was now recording an average 20-ft wind speed of 12 MPH. It was bearing down on about 20 dwellings with few suppression resources available to check it's spread. At 2040 hrs the constructed line was completely abandoned along Spruce Creek Road. Maximum gust wind speeds measured at the Cyclone Peak RAWS during this time reached 49 MPH, winds then started to gradually abate finally dropping to average wind

Figure 13. September 6th 1800 hrs and September 7th 0600 hrs radiosonde plot from Spokane, Washington.

Spokane Radiosonde
Station Elevation 2357'



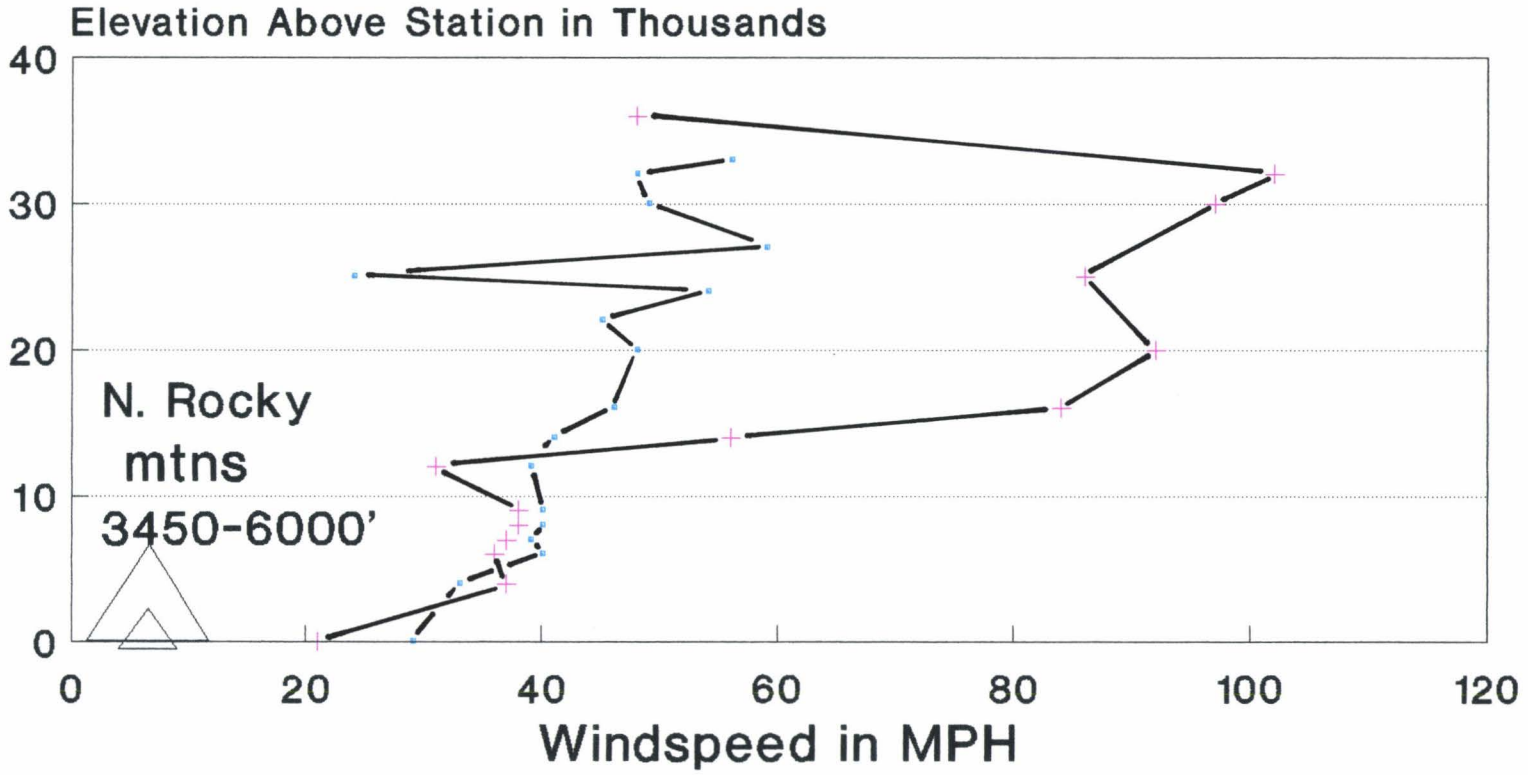
Sept 6, 1800 hrs
Type 2-b Profile

Sept 7, 0600 hrs
Type 2-a Profile

Figure 14. September 6th 1800 hrs and September 7th 0600 hrs radiosonde plot from Great Falls, Montana.

Great Falls Radiosonde

Station Elevation 3751' msl



Sept 6, 1800 hrs
Type 4-a Profile

Sept 7, 0600 hrs
Type 3-c Profile

speeds in the single digits by about 0400 hrs, gusts remained mostly above 25 MPH.

The forward spread declined considerably under the diminished winds, but the fire remained very active throughout the night as the interior of the fire continued to burn (Figure 15). It was estimated that by 2330 hrs the fire perimeter, including areas of spot fires, had grown to 2,027 acres. Fuel moistures, especially at the higher elevations, continued to climb with the rising relative humidity behind the frontal passage. Shortly after daylight arrived (0600 hrs) on September 7th the Cyclone Peak RAWS was recording 1-hour Timelag Fuel moisture at 12%; near the fire front the fuel moistures were lower, between 8.0% and 8.5%. By 0630 hrs the fire was known to have crossed the North Fork Road in sections 7, 8, and 17 but had not yet crossed the North Fork of the Flathead River (average forward ROS since crown fire initiation of about 0.3 MPH; approximate forward ROS at this time was also down to about 0.2 MPH).

In unburned fuel near the fire's origin the calculated 1-hour fuel moisture climbed to between 12% and 13% between 0600 and 1200 hrs with the Probability of Ignition of a spot fire dropping to 20%.

By 0800 hrs several houses were known to be within the fire perimeter but none had been confirmed as having been destroyed. The Missoula Fire Weather Office canceled the "Red Flag" conditions because the "windy conditions were general over the area and well advertised." However the Fire Behavior Service Center kept the Fire Behavior Warning in place noting that the continued strong winds and very dry fuel conditions would contribute to extreme and erratic fire behavior throughout the day.

The wind profiles from the morning 0600 hrs radiosonde readings taken at Spokane, Washington and Great Falls, Montana showed exceeding strong winds at

higher elevations. A Type 2-a wind profile with the continued presence of a low-level jet-point was indicated at Spokane. This is one of he most dangerous wind profile types. The profile is of particular concern when the jet-point occurs at or near the level of the ongoing fires, a particular problem in mountainous terrain. Fire behavior characteristics for Type 2-a profiles may include fire whirls within convection columns contributing to spotting, long distance spotting, and towering convection columns (Byram 1954). Wind speeds associated with the Spokane profile increased rapidly above 15,000 ft msl (13,000 ft above the Spokane station), with speeds in excess of 120 MPH above 22,000 ft msl. The radiosonde from Great Falls indicated a Type 3-c profile strongly influenced by mountainous terrain to the west. The Type 3-c profile has very high wind speeds at the jet-point which then drop off with increasing elevation (reverse wind profile) for several thousand feet above the jet-point elevation. Wind speeds at the upper elevations of the profile were also very high. Under the influence of this type of wind profile convection columns may sometimes build up for short periods of time and contribute to long distance spotting before being destroyed by the wind. An erect convection column though is not necessary for fires under the influence of this wind profile to spread rapidly driven by strong winds (Bryam 1954). Most of the extremely strong winds were still occurring further to the south in the vicinity of the Canyon Creek Fire. The dry-cold front had temporarily stagnated south of that fire in the Scapegoat Wilderness and was contributing to extreme fire behavior on the interior of the fire which would grow by about 117,330 acres during the September 6th and 7th burning period (Bushey 1990).

Between the hours of 0630-1300 the Red Bench Fire was only able to maintain a forward ROS of about 0.06 MPH. During this time Cyclone Peak RAWS average 20-ft wind speeds stayed mostly below 9 MPH with maximum gusts in the mid 20

Figure 15. Crown fire behavior during the night of September 6, 1988 on the Red Bench Fire. Photograph likely taken either along Spruce Creek or Red Meadow roads.

MPH range. Calculated midflame wind speeds dropped to between 0.4 and 1.0 MPH. The fire dropped to the surface with considerable torching of conifers taking place as surface fuel burned beneath the trees. 1-hour Timelag Fuel moisture beneath the forest canopy near the fire front declined to 7.6% by noon (Probability of Ignition of spot fires was 40%), the fire at this time was approaching the river in sections 8 and 16 in a combination of heavily forested riparian and dense lodgepole pine stands (Figure 16). At 1300 hrs the average 20-ft wind speeds were again starting to increase with gusting winds up to 25 MPH causing fire brands from torching trees to be thrown across the river in section 8 above the River Campground. Once the spot fires were established on the east side of the river they immediately took off forcing fire fighting personnel to pull back. One fire crew was cut off on the north side of the fire as it started to run through the a combination of forest and grassland surface fuels, torching areas of conifers. Within 8 minutes of crossing the river the fire had run approximately 0.75 mile. This event happened so quickly that the aerial patrol had made a loop across the river and over the Park and reported no fire, then was flying back west over the fire when the Cyclone Peak Lookout reported the fire crossing the river. By the time the aerial patrol had turned around and was again over the fire front in had already traveled the 0.75 mile distance passing through Big Prairie and in to dense lodgepole pine forest. The fire ran through dry (1-hour fuel moisture content of 6.5%, no forest canopy but 100% shade factor from convection column) fescue grasslands with scattered encroachment of lodgepole pine and ponderosa pine. Flame lengths through the grasslands were estimated visually to be between 6 and 8 feet and ROS about 5.2 MPH (calculated average flame length under the influence of maximum mid-flame wind speeds between 10 to 11 feet, ROS 2.1 to 2.5 MPH). Conifer overstories became quickly involved when the fire encountered them

contributing to additional spotting fire behavior. This was especially true of the downwind lodgepole pine forest which the fire rapidly moved in to. ROS decreased significantly as the fire entered the lodgepole pine forest only traveling 0.3 miles during the next 22 minutes (1400 hrs). This dropped the average observed ROS between 1300 and 1400 hrs down to 1.2 MPH, still the highest average ROS yet observed on the fire (Figure 17). Wind speeds were averaging 10 MPH with maximum gusts to 37 MPH.

Most of the forward fire spread during the late afternoon and early evening was in the lodgepole pine forest inside Glacier National Park. As the fire entered the lodgepole pine forest southeast of Big Prairie it began to enter areas of heavy, jack-strawed, dead lodgepole pine with standing lodgepole pine overstory. By 1400 hrs the fire had begun to "blow-up" in these areas of heavy dead fuel concentration. During the next 2 hours the average observed crown fire ROS dropped slightly to about 0.6 MPH, then between 1600 and 1900 hrs as the fire encountered some upslope conditions above 3,600 ft msl the ROS increased to 0.9 MPH under average wind speeds of 8 to 12 MPH and maximum gusts of 30 MPH. Calculated ROS based on 12 MPH average wind speed, and depending on crown biomass, varied between 0.6 to 0.9 MPH with flame lengths between 40 to 80 feet in height with the fire being powered by the fire (Pf/Pw=3-4)(Figure 18). Under periodic peak wind conditions of 30 MPH the fire would have had an occasional ROS of between 1.5 and 3.0 MPH and flame lengths of 80 to 180 feet in height and be marginally powered by the wind (Pf/Pw=0.5-2.3). Some reports indicated flame lengths to be 200 to 300 feet in height above the tree tops, with exploding gas balls within the convection column as the fire entered in to an area of lodgepole pine forest which contained some of the heaviest dead and down fuel loadings. Some of the greater flame lengths likely included burning gasses from the conifer forest. Tree tops were again observed to be torn off

Figure 16. Northern Rocky Mountain region as photographed on September 7, 1988 at approximately 1200 hrs by the Polar Orbiting Satellite (AVHRR). The Red Bench Fire convection column can be seen mixed with the scattered clouds behind the dry-cold front which traverses the photograph from east to west in the upper third. The configuration of the convection column is indicative of strong winds near the surface. Right on the leading edge of the stagnated frontal system can be seen the Canyon Creek Fire in the Scapegoat Wilderness with its convection column entrailed within the low level jet-stream. This column is tightly braided and still solidly intact approximately 300 miles downwind. Below and to the left of the Canyon Creek Fire can be seen scattered convection columns of fires burning in the Selway-Bitterroot Wilderness. To the right and below the Canyon Creek Fire are the wide fan-shaped convection columns of the many fires burning within and adjacent to Yellowstone National Park. This is a more typical smoke dispersal pattern.

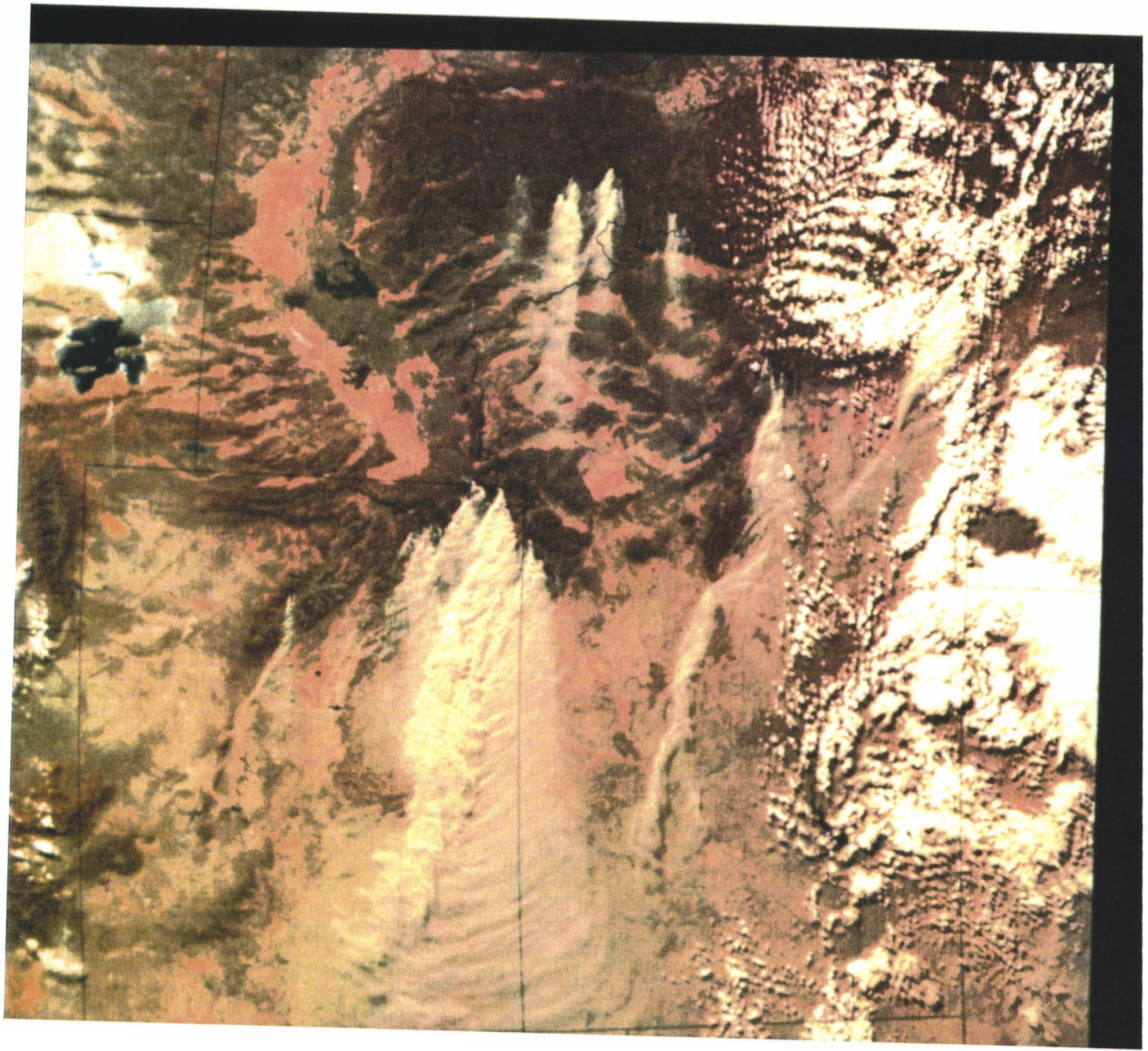
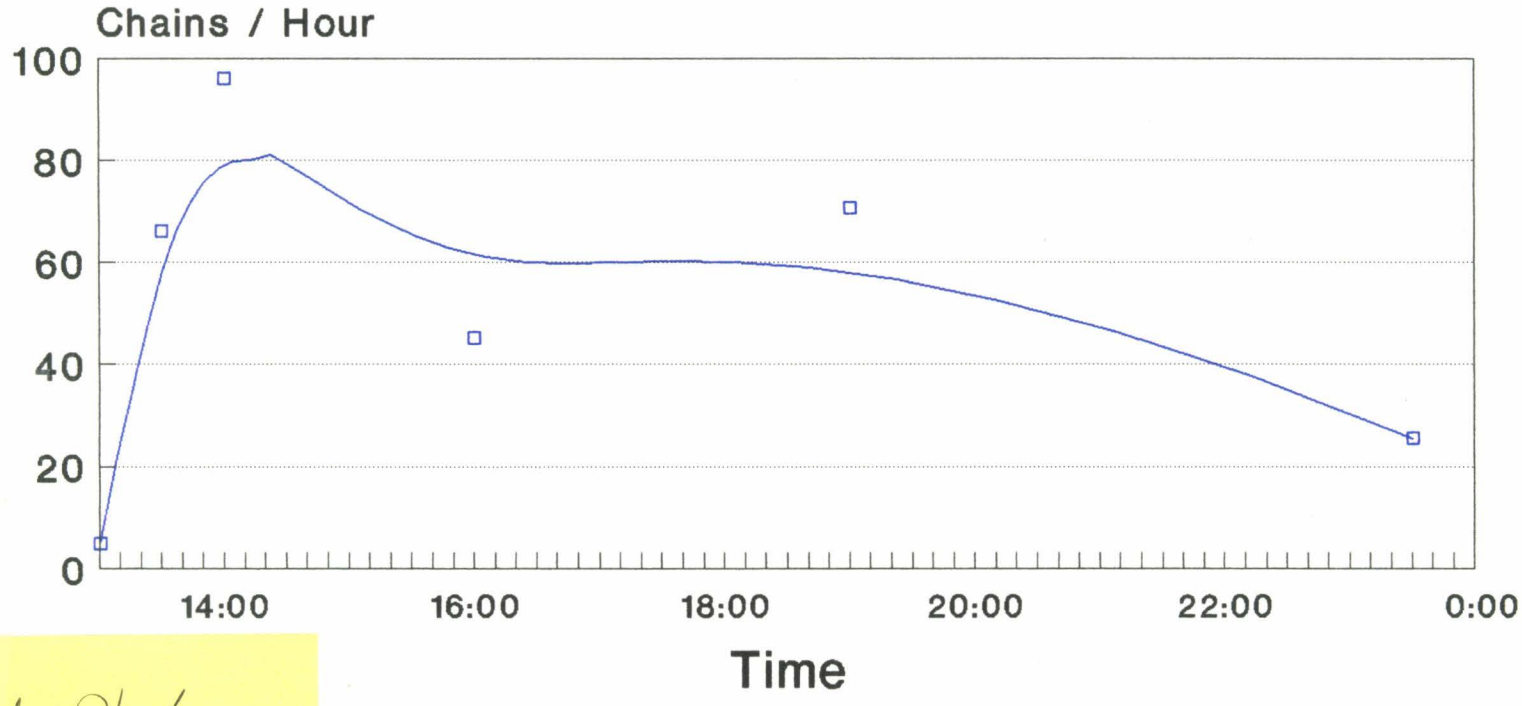


Figure 17. Red Bench Fire forward rate-of-spread from 1300 - 2330 hrs on September 7th during the period of "blow-up" conditions within Glacier National Park. The period of peak rate-of-spread includes the fire run through the Big Prairie grasslands, after which the fire entered sustained "blow-up" conditions in heavy, dead and down lodgepole pine forest with a gradual decline in spread with rising evening fuel moisture levels.

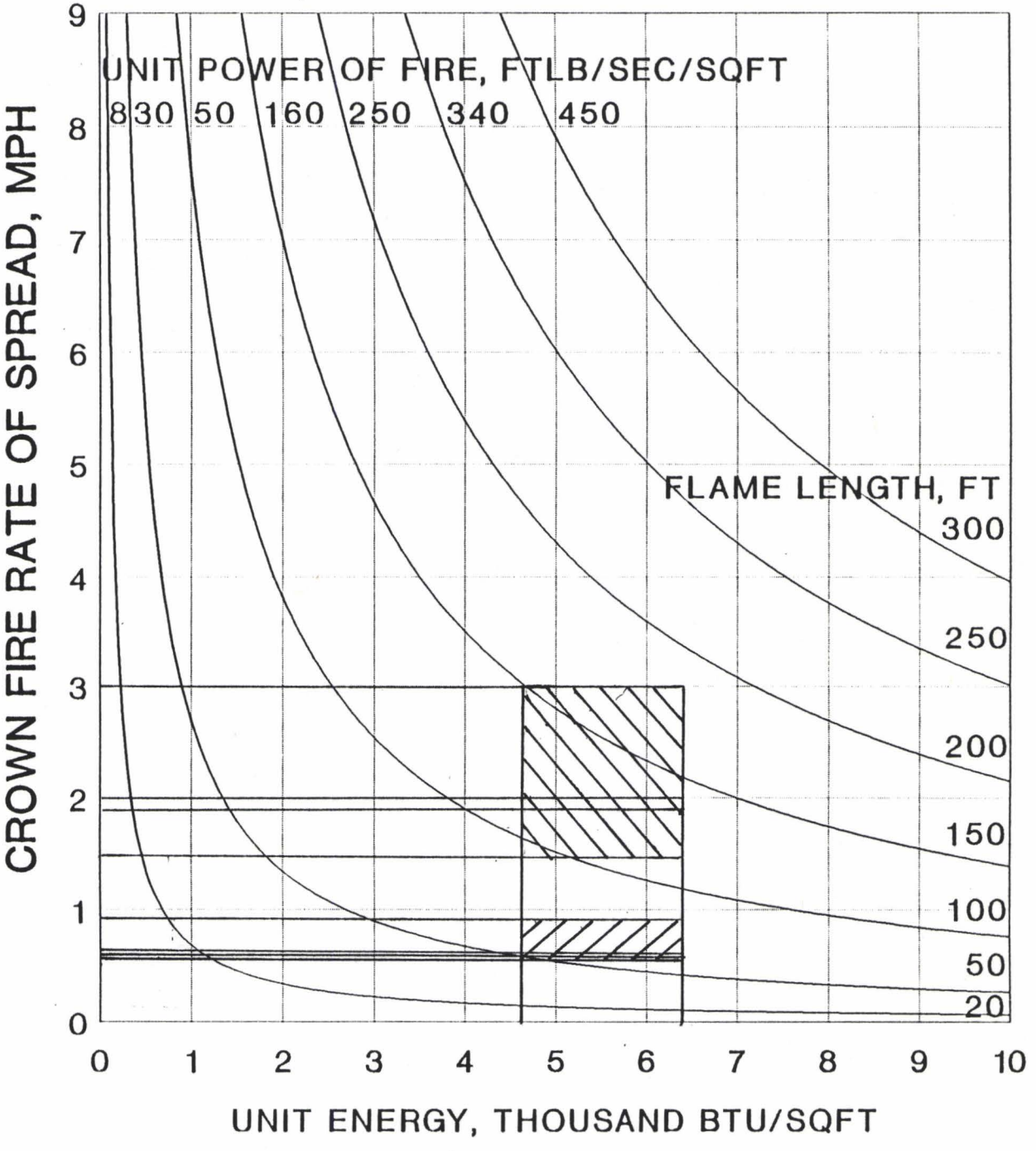
Red Bench Fire
Forward Rate-of-Spread



16 Sat Photo
17 ROS2

Red Bench Fire (1988)

Figure 18. Fire behavior characteristics chart for the "blow-up" crown fire run within Glacier National Park of the Red Bench Fire, 1400 - 1600 hrs. Input included crown biomass range of 3.0 - 8.0 T/AC, Fuel Model 12 surface fuel, and 12 MPH average 20-ft wind speed with peak wind speeds of 30 MPH. Horizontal lines from top to bottom within each box represent 1) near maximum rate-of-spread, 2) upper 75% confidence level rate-of-spread,3) average rate-of-spread, and 4) lower 75% confidence level rate-of-spread. Top box with diagonal lines is the calculated range of fire behavior at 30 MPH, the lower box with diagonal lines the fire behavior at 12 MPH.


UNIT POWER OF FIRE, FTLB/SEC/SQFT
8 30 50 160 250 340 450
FLAME LENGTH, FT
300
250
200
150
100
50
20
CROWN FIRE RATE OF SPREAD, MPH
0 1 2 3 4 5 6 7 8 9
0 1 2 3 4 5 6 7 8 9 10
UNIT ENERGY, THOUSAND BTU/SQFT

and sent flaming through the air, starting new spot fires when they landed (Figure 19). During this period the 1-hour fuel moisture levels were between 7.0% and 9.0% with a Probability of Ignition of spot fires of 40%. Also during this time period, the afternoon temperatures near the river started to drop following a peak of 62F with a low relative humidity of 32%. Between 1900 and 2330 hrs the fire front had an average observed ROS of 0.3 MPH as rising fuel moistures helped slow the fire. This forward portion of the fire had progressed about 6.1 miles in to the Park in a southeasterly direction and had climbed to about 4,600 ft msl since crossing the river 10 hours earlier.

When the wind speed began to increase during the afternoon of September 7th the wind also shifted out of the northwest causing the entire southern flank of the previous days fire to become active, forming a new fire front out of the former fire flank (Figure 20). In the riparian and lodgepole pine forests west of the river the fire front was moving parallel to the river with a ROS of about 0.3 MPH between 1300 and 1600 hrs and 0.4 MPH between 1600 and 1900 hrs. By 1600 hrs it was evident to the fire fighters that the Polebridge Ranger Station on the east bank of the river, the wooden bridge crossing the river at that location, and homes on the northern outskirts of the community of Polebridge would be threatened by the approaching fire and efforts were concentrated on protecting these structures. By 1900 hrs the Polebridge Ranger Station adjacent to the river was being burned over from the southern fire spread and all efforts to protect the site was abandoned. At approximately 2100 hrs the fire on the west side of the river dropped out of the tree crowns surrounding the community of Polebridge and turned in to a wind driven grass fire with flame lengths of 1 to 2 feet in height. The fire burned through the mostly short (4 inches) grass between the buildings in town, following areas which had remained ungrazed or mowed and along stream drainages with mature

overstories of black cottonwood (Populus nigra) with scattered spruce, lodgepole pine, and subalpine fir in the understory reaching in to the cottonwood crowns. Heavy shrub and herbaceous fuel loadings also were available within the riparian zones. Out of 100 total dwellings within the fire area, 15 were destroyed and another 5 out buildings were lost where dwellings were saved. Fire fighters remained in the community as the fire swept through, successfully saving many structures that otherwise would have been destroyed. Calculated conditions near the river at 2100 hrs were temperatures of 53F, relative humidity 31%, average 20-ft wind speeds of 13 MPH, 1-hour fuel moisture content 8.0%, and Probability of Ignition of spot fires 30%. Between 2100 and 2200 hrs the wind velocity eased and the fire behavior became noticeably reduced. During this day the fire increased in size by approximately 12,666 acres, bringing the total within perimeter fire size to about 14,683 acres.

As the early morning hours of September 8th arrived temperatures began to drop significantly, down to 39F at Cyclone Peak RAWS and at least down to 28F by 0700 hrs at the newly established fire camp. As the temperatures and wind velocities dropped a temperature inversion developed trapping thick smoke in the lower elevation valley. By 1200 hrs the temperature had risen to 59F at the RAWS and 57F in the valley. First signs of the inversion starting to lift in the lower elevations was at 1300 hrs. Temperature at the RAWS had risen to 62F, relative humidity down to 25%, and 1-hour fuel moisture had dropped to 5%. As the inversion lifted the fire again became active with all areas beginning to report high intensity fire behavior by 1330 hrs; this included spotting, torching, and crown fire behavior. Winds had switched out of the south and west and were between 5 and 8 MPH, halting the previous days fire spread to the southeast. In many locations along the fire's southern perimeter

Figure 19. Prominent convection column of the Red Bench Fire during "blow-up" crown fire run on Septmber 7th inside Glacier National Park. This photograph was taken by Harold and Rachael Sweet from their cabin, southwest 1/4, Section 5 looking south toward the Polebridge Ranger Station as the fire burned through lodgepole pine forest with heavy dead and down fuel.

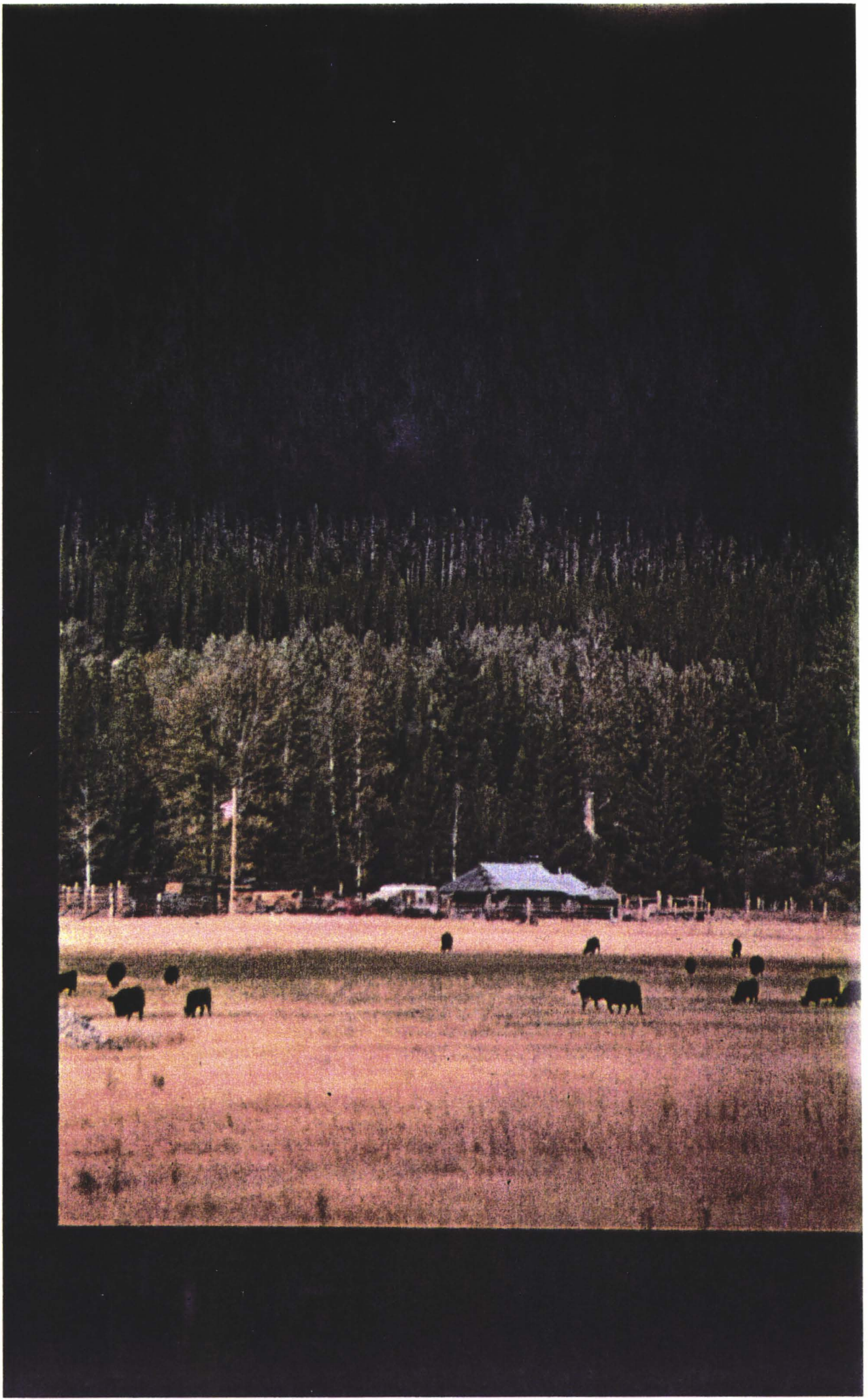


Figure 20. Blackened sky from the convection column during the afternoon of Septmber 7th as the former southern flank of the Red Bench Fire developed in to a flaming front driven by winds from the north-northwest. This photograph with the cattle still grazing peacefully was taken in the northwest 1/4, Section 34 looking northeast as the crown fire moved through the lodgepole pine forest toward the community of Polebridge.

the wind shift was causing the fire to burn back in on itself aiding the fire suppression efforts. At the higher elevations though, the wind direction was out of the north to northeast and increasing in velocity. By 1400 hrs the 1-hour timelag fuel moisture as measured at the Cyclone Peak RAWS had dropped down to 4% and average 20-ft wind speeds were starting to exceed 10 MPH with even stronger gusts. Several separate convection columns were reported on the fire at this time. During the next hour the various fire fighting divisions reported difficulty in holding their fire lines, and one area was reporting numerous spot fires beyond the line. Between 1500 hrs and 2000 hrs the fire displayed extreme fire behavior with crown fire ROS of 1.5 to 1.8 MPH, flame heights up to 300 feet reported, and with a very large convection column spotting up to 1.5 miles distance. During the day, until 1500 hrs, the main fire front within the Park advanced 1.25 miles with principal spread to the south and east. The fire also began to move in a northerly direction in the vicinity of Akokala Creek toward Tepee Flats inside the Park. While the area of fire in the Akokala Creek drainage was principally a flanking fire it would have been difficult to convince the personnel in that sector who were viewing large areas of timber "crown out" that this was not the "main" fire front. Between 1500 and 0200 hrs the main fire front in the Park interior had moved forward another approximate 3.8 miles in an easterly direction through Quartz Creek and Cummings Creek drainages and along Logging Ridge to an elevation above 5,200 ft msl.

Also during the afternoon burning period fires starting from fire brands dropped during the first afternoon's fire run along Red Meadow Creek swept from above the creek burning up slope and back in to the original fire run. One of these up slope fire runs started from spot fires and flanking fire in the unburned "leave strip" between Logging Units 2 and 3. Unit 2 burned and the

eastern 66% of Unit 3 burned as the fire swept up hill and to the southeast moving to the ridge top as well as reburning a portion of the area previously burned on September 6th, including the fire's origin. In some of the higher elevation areas the fire remained active throughout the night as thermal belt conditions developed in associated with a temperature inversion, reinforced by a weak subsidence inversion. The wind speeds dropped from an average velocity of 11 MPH to 3 MPH and fuel moistures rose between 2000 and 2100 hrs. There was very little fire activity visible from the fire camp by 2200 hrs and in most areas the fire remained calm.

The morning of September 9th (0200 hrs) was the first time that the fire perimeter could be mapped using infrared imagery to determine fire size. As a result a more accurate size resulted, raising the fire to 28,236. This was an additional increase of 13,553 acres, most of which had occurred the previous day but also included some earlier under estimations of within perimeter acreage. At about 0600 hrs winds were calm under the heavy inversion and there was a 13F difference in temperature between the lower elevations and where the Cyclone Peak RAWS was located. Beneath the inversion the relative humidity at this time was 100%, while above it was 48% with a declining fuel moisture content. Later (0900 hrs) the winds remained light and the fire was reported to be active at 5,600 ft msl on a southerly exposure on the ridge above the fire's origin. This area of fire was reported to be an expanding spot fire from the previous days activity. The lower elevation portions would not experienced the breaking of the inversion layer and sunshine until 1443 hrs. As soon as the inversion broke the winds started to gust and within 2 minutes of the sun breaking through all areas of the fire perimeter became active. By 1500 hrs the inversion had completely lifted. Most new fire activity after the inversion lifted was along the northern flank of the fire in the areas of Tepee

Flats, Quartz Ridge and Quartz Creek. These were mostly southerly exposures which experienced up slope spread. The greatest area of spread during the day was in Tepee Flats where the fire advanced up to another 0.9 mile. 20-ft winds peaked during the burning period at about 1700 hrs with average speeds of 9 MPH with gusts to 20 MPH, however by this time fuel moistures were already rising again. The light winds during the day helped keep the fire behavior to a minimum.

During the morning of September 9th a "Red Flag Watch" was issued by the Fire Weather Office forecast for winds during the upcoming night from another approaching frontal passage. The watch was changed to a "Red Flag Warning" by 1800 hrs with expected winds of 5 to 15 MPH and gusts from 15 to 30 MPH. The approaching cold front posed danger for increased fire behavior on the east and southeast portions of the fire's perimeter. The front had moved in to northwestern Montana during the afternoon but had not advanced any further. However, the expected winds did not arrive during the night and the increase in fire activity that the fire crews were preparing for did not occur. Fire size mapped during the early morning hours indicated that an additional 2,226 acres were now included in the fire perimeter from activity on the 9th. This brought the total within fire perimeter size to 30,462 acres.

As the morning arrived on September 10th the sky was overcast and temperatures were in the mid to upper 40F range, and relative humidities varied depending on location from the upper 40% range to the mid 50% range. The winds which had remained light during the night increased slightly after sunrise to between 5 MPH and 8 MPH, and the clouds began to thicken (Figure 21). Light rain began to fall about 1000 hrs and by noon the Cyclone Peak RAWS had received 0.09 inches of precipitation with relative humidities rising to 94%. Above 5,500 ft msl on the fire a report of "heavy" snow was received but no

measurements. The moisture and increased relative humidity at the lower elevations raised the fuel moisture content in the smaller diameter fuel particles but had little impact on the larger fuel (Figure 22). Fuel moistures beneath forest canopies were only affected by the rising relative humidities. Observed fire behavior during the day remained relatively insignificant with creeping and smoldering spread and flame lengths generally less than 12 inches in height. The stronger winds expected to arrrive with the frontal passage never did develop with average winds peaking at 12 MPH at 1400 hrs in the afternoon. Weather stations south of the Red Bench Fire received greater amounts of moisture. Areas along the eastern front range of the Northern Rockies began to receive significant amounts of moisture in various mixtures of rain and snow which effectively halted fires burning in those areas (Bushey 1990).

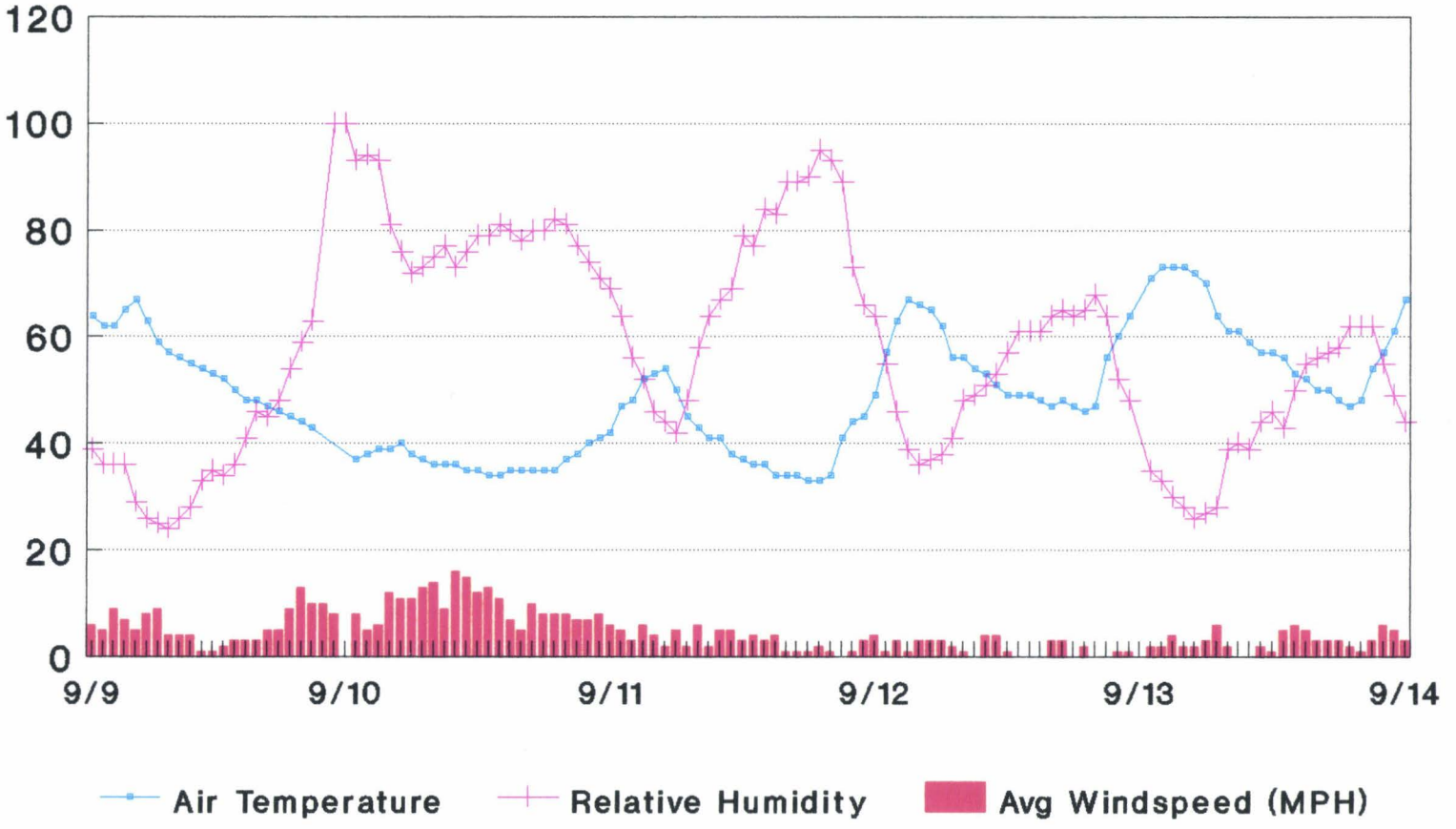
Skies were still cloudy, temperatures in the low 40F's, relative humidities in the upper 60% and low 70% range, with light winds on the morning of September 11th. Fire behavior had increased slightly from the previous day to surface fire with 2 foot flame lengths with a ROS of about 2 feet per minute. Some minor torching activity was also reported with firebrands only spotting about 2 feet distance. By 1320 hrs the skies above the fire had begun to clear and fire activity started to pickup all along the fire's perimeter with increased torching and spotting behavior with flame lengths reported up to 4 feet. Spotting distance remained only a few feet with afternoon wind speeds generally less than 2 MPH. Most of the fire remained beneath the forest canopy on the surface only scorching lower branches of the conifers, seldom entering in to the tree crowns themselves.

During the early morning hours of September 12th the Cyclone Peak RAWS reached 34F, while down in the river valley the fire crews woke-up to a heavy

Figure 21. Fire weather from the Cyclone Peak RAWS for the period noon September 9th through noon September 14th; including temperature, relative humidity, and average 20-ft wind speeds.

Fire Weather

Cyclone Lookout RAWS (3241915E)

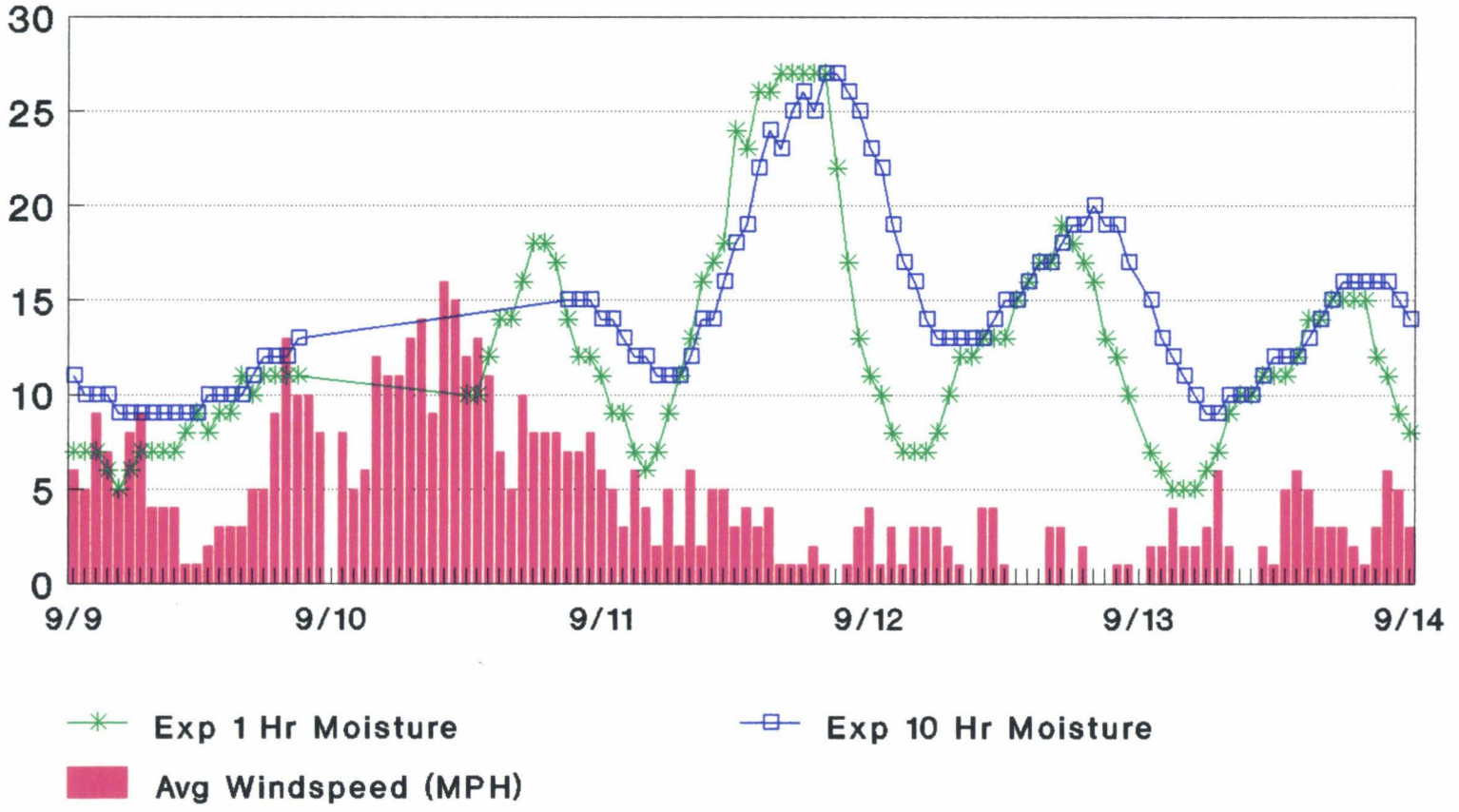


Red Bench Fire (1988)

Figure 22. 1-hour and 10-hour fuel moisture contents and average 20-ft wind speeds from the Cyclone Peak RAWS for the period noon September 9th through noon September 14th.

Fire Weather

Cyclone Lookout RAWS (3241915E)



Red Bench Fire (1988)

frost and 23F temperatures at 0600 hrs. After the inversion layer broke and the sunrise reached the fire camp (1006 hrs) the temperatures climbed rapidly. By about 1300 hrs under fairly calm conditions the fire activity was low with flame lengths of 0.5 feet, ROS about 0.1 feet per minute, and occasional spotting distances of 3 feet. Fire was concentrated in areas of heavy dead and down fuel which still remained dry. Winds remained calm throughout most of the burning period except for a brief time at 1600 hrs when speeds increased to 5 MPH and more active fire behavior was reported. High pressure had begun to rebuild over the Northern Rockies after the frontal passage the previous day. The high pressure was expected to remain over the area the next several days and contribute to a warming and drying trend. By the end of the day the size of the fire was mapped at 31,557 acres, which was an increase of 1,095 acres during the previous three days.

Morning temperatures were again cold on September 13th but not nearly as cold as the previous morning, only down to 27F at the fire camp and 47F at the Cyclone Peak RAWS. The entire fire was socked in with thick smoke beneath the temperature inversion layer which did not break until early afternoon. Fire activity started to increase about 1326 hrs when one of the perimeter divisions requested some water drops to help lower the fire intensities. At this time the temperatures had risen to the mid-60F's and relative humidities had dropped in the low 40% range over the fire. 1-hour timelag fuel moistures were reported around 8-9%. By 1500 hrs the wind started to increase to 5 MPH and the surface fire began to climb ladder fuel with moderate torching observed. At 1630 hrs the torching had thrown several firebrands across the fireline which were smoldering. Within 15 minutes the wind speeds had increased to 4-5 MPH at eye level and 8-10 MPH at 20-ft as 1-hour fuel moisture reached a low of 4%, and the spots were making a minor run with an estimated ROS of about 0.2

MPH with flame lengths of 6-7 feet. The run did not last very long as the winds calmed and by 1748 hrs fire behavior decreased with only occasional torching. Fire was inactive through the night.

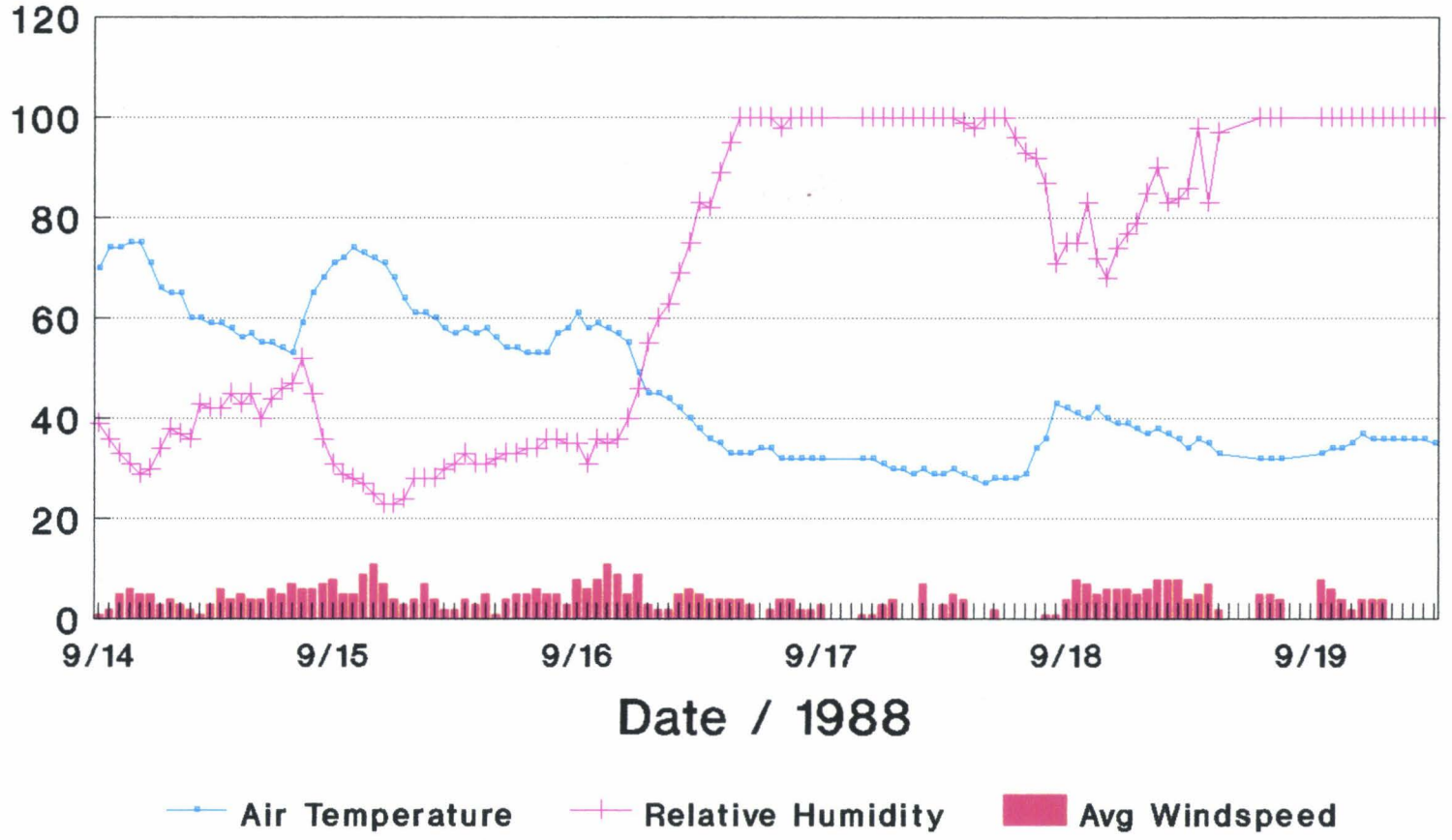
Temperatures were again slightly warmer on the morning of September 14th, getting down to 31F at the fire camp with smokey conditions beneath the temperature inversion, 47F at the Cyclone Peak RAWS within the inversion. By about 1100 hrs the 1-hour fuel moisture content had again declined to about 8-9% and reports started to arrive of increased fire behavior with minor torching, spotting and fire runs. Whenever the wind speeds would increase slightly the fire behavior increased, then rapidly decrease when calm conditions returned (Figures 23 - 24). This type of activity continued throughout the day. Temperatures during the day reached the low 70F's with relative humidities in the low 30% range. By the end of the day a remapping of the fire perimeter showed a growth of 300 acres during the last two days, bringing the total within perimeter fire size to 31,857 acres. The high pressure system was expected to hold over the area for another 24 hours after which a southwesterly air flow would develop followed by a Pacific frontal system.

September 15th temperatures were similar to those experienced the previous two days, with slightly lower relative humidities. A weak inversion lifted early. Approximately 1300 hrs saw the relative humidity readings decline to the mid-20% range over the fire, while at the same time wind speeds increased with gusts of 8 to 10 MPH. About this time the fire behavior began to increase, as it had on previous days with increased torching and spotting. Most of the increased behavior occurred along Quartz Ridge on southwest aspects exposed to the generally west to southwest wind flow. Wind speeds continued to increase until reaching averages of 8-10 MPH with gusts 19 to 25 MPH at eye

Figure 23. Fire weather from the Cyclone Peak RAWS for the period noon September 14th through midnight September 19th; including temperature, relative humidity, and average 20-ft wind speeds.

Fire Weather

Cyclone Lookout RAWS (3241915E)

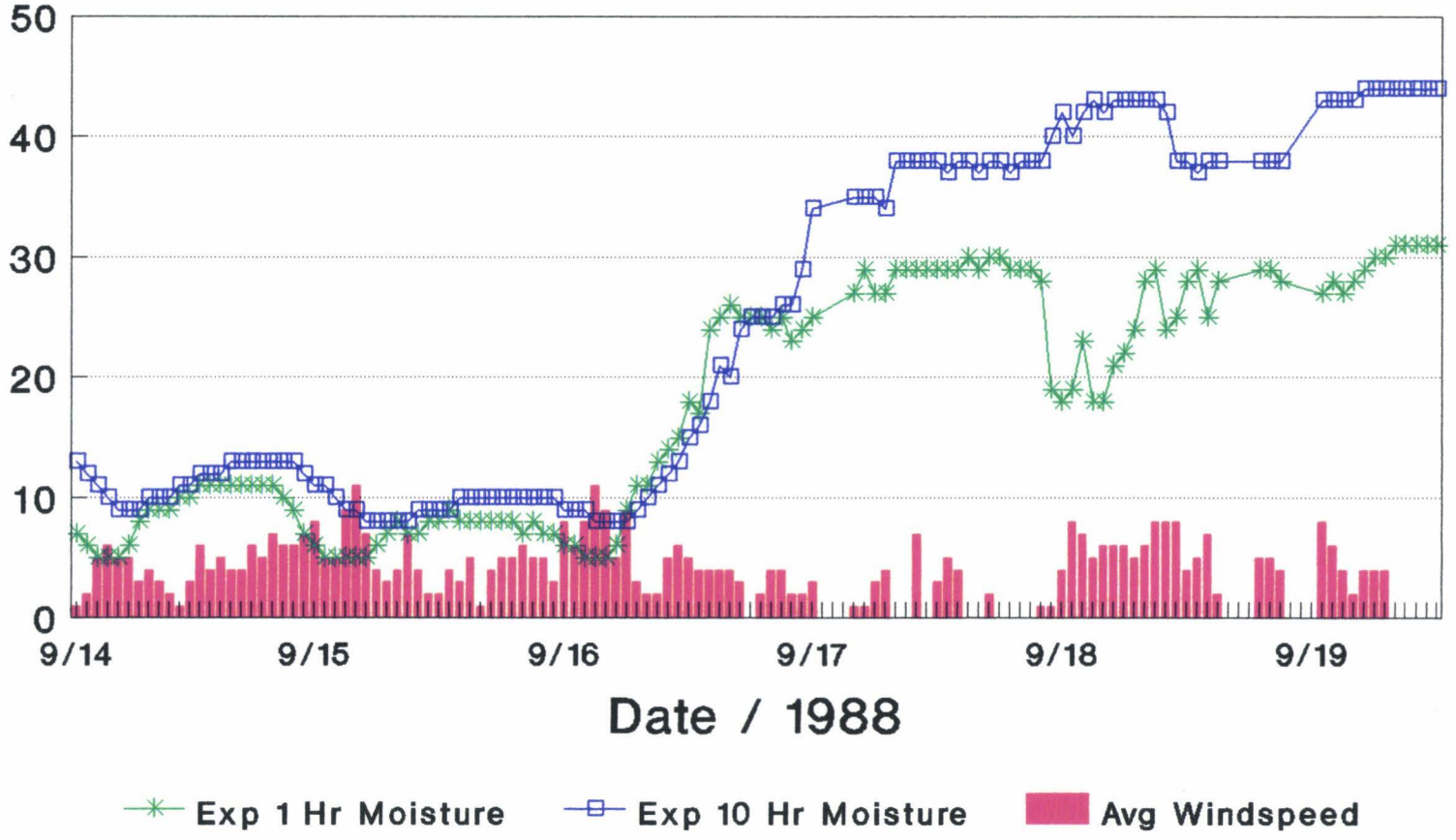


Red Bench Fire (1988)

Figure 24. 1-hour and 10-hour fuel moisture contents and average 20-ft wind speeds from the Cyclone Peak RAWS for the period noon September 14th through midnight September 19th.

Fire Weather

Cyclone Lookout RAWS (3241915E)



Red Bench Fire (1988)

level. Above the canopy the wind was reported to be blowing much harder with considerable eddying. With the stronger wind, flame lengths were reported to increase to 50 feet with an ROS along the ridge of 0.9 MPH through lodgepole pine-subalpine fir forest with estimated 25 to 30 tons per acre of surface fuel. Some long range spotting of 0.5 to 0.75 mile were reported. An estimated 5 miles of fireline was lost and many crews had to retreat to safety zones about 1800 hrs. The fire remained very active until about 2000 hrs.

Overcast skies and relatively warm morning temperatures of 43F (0600 hrs) were reminders of the predicted approach of a Pacific frontal system which forecasters had the "Red Flag" out for. This was expected to move through northwestern Montana during the morning with most moisture in the system staying north in to Canada. Torching along Quartz Ridge was reported as early as 0945 hrs as temperatures climbed up to 56F and relative humidity down to 39% under light wind. By 1100 hrs temperatures had warmed to 63F with relative humidity down to 27% with light, gusty winds and the fire was actively torching and attempting to begin crown fire runs. This conditions remained relatively constant until about 1400 hrs when wind speeds increased to 15 to 20 MPH with gusts to 30 MPH along the ridge top causing the fire to crown and advance another 2 miles. Winds averaged between 4-12 MPH during this time at lower elevations with conditions described as moderate to very gusty causing a "blowout" of a corner of the fire in the northwest corner of Akokala Creek as well. By 1900 hrs the fire size had grown 33,290 acres with 1,403 acres added since the morning of September 15th. The crown fire activity continued until about 2000 hrs. Remapping the fire the next day showed an additional 2,090 acres within the perimeter by the end of the burning period bring the fire size to 35,380 acres.

That next morning of September 17th again started overcast, with a light rain starting about 0730 hrs. By 1030 hrs a mixture of rain and snow was falling in the fire camp. It was primarily snow falling and then melting by 1125 hrs with temperatures in the mid-30F range. At 1208 hrs the snow was sticking and accumulating at the 4,200 ft msl elevation. The accumulating moisture was penetrating up to 0.25 inch in to the fuel reducing the fire behavior to smoldering. Weather stations south of the fire had received between 0.24 and 0.4 inches by 1400 hrs. 0.36 inches fell in camp by 1800 hrs and 3 inches of snow accumulated at the 4,200 ft msl level. By dark the trees several hundred feet above the fire camp elevation along the river were "frosted" with a light layer of sticking snow. The fire remained quite throughout the night.

Moisture continued to arrive the next two days with the eventual total precipitation received at the Cyclone Peak RAWS being 1.17 inches (including snowmelt). On the 19th of September the 0930 hrs day shift was canceled and the fire crews moved to dry shelter. On the 20th demobilization was started. By the 28th the fire was listed as contained with no additional spread occurring since the early morning hours of the 17th. A return to warmer and dryer conditions would occur during October and the Red Bench Fire would continue to smolder and occasional produce areas of low intensity fire late in to the month before winter snows finally extinguished the last of the fire.

Concluding Remarks

The Red Bench Fire was the result of a lightning caused ignition which due to the concurrence of dry fuel, warm weather, subsidence inversion, and strong gradient winds associated with a dry-cold front passage made an unusually rapid and large sustained fire run. The influence of a reverse wind profile with a

low-level jet point is known to have occurred at the time of the fire run but is believed to have had a greater effect on ongoing fires further south of the Red Bench Fire. Without the presence of the initial strong gradient winds the Red Bench Fire would not have achieved the size it did during the first two days of the fire run. In fact the lightning caused fire might not even have been discovered if winds had remained relatively calm before the arrival of the end of the fire season rain and snow.

The proper weather conditions needed for a smoldering fire to develop in to a crown fire in the vicinity of the Polebridge Ranger Station are an unusual, through not rare occurrence. Out of the entire (1951-1988) fire weather record from the station only 83 days out of 3,049 had adequate conditions to initate a crown fire. Of those 83 days August had the greatest amount (47 days) while September only had 8 days. This of course assumes that a fire has been actually ignited during those specified days and that sufficient fuel is available for it to burn as well as no barriers to prevent the fire from spreading. The estimated return interval for the necessary conditions for initiating a crown fire during August was approximately 1 day each 1.7 years, and during September (based on limited data) 1 day each 2.8 years.

Based strictly on the Fire Danger ratings from the Polebridge Ranger Station from 1988 and comparing those with other recognized "severe" fire danger seasons, 1988 at this location did not qualify as a very severe fire season. Further south along the Northern Rocky Mountains the Fire Danger ratings during 1988 did compare with other known severe seasons. If a particular fire season were to be utilized as an example of a severe fire season for fire behavior prediction purposes the 1967 season would be a much better choice at the Polebridge location. Most of the 1988 season followed

relatively closely to the average Fire Danger (1973-1988) at the Polebridge Ranger Station.

Only recently have large fires been documented describing those fires and their behavior by individuals trained in fire behavior. In the vicinity of the Red Bench Fire the last large fire had occurred in 1926 and information is scanty. From what we do know the orientation of fire spread and perimeter pattern of the two fires are similar. This would indicate that the 1926 fire and the Red Bench Fire may have burned during portions of their life span under similar weather and fuel conditions as influenced by the same topographic features. A future ignition in the same general vicinity after the forest fuel has become reestablished could be expected to again burn in much the same pattern under the influence of a late fire season dry-cold front. It is interesting to note that most years the transistion from summer to autumn during the last week of August or the first week of September in the Northern Rockies is accompanied by a strong cold front passage. Most years this frontal passage brings sufficient precipitation to effectively end the fire season (in Missoula, Montana this event is termed the "August Singularity" and has provided significant moisture during 21 of 23 years between 1966 and 1989). In those years when moisture is not provided by the frontal system strong winds are an important feature; and ongoing fires, and even undiscovered starts, have the potential to make a large sustained fire run such as the Red Bench Fire did. Strong sustained winds are a necessary ingredient for a fire in the fuel types in and around Glacier National Park to burn large acreage. The Red Bench Fire was a good example of this scenario.

During the last decade our abilities to predict the possibility of large fire occurrence and behavior have improved considerably. There are still many unknowns, such as knowing the Red Bench Fire was smoldering and waiting to

run. But our skills in tracking Fire Danger, fuel moistures, and weather conditions have improved to the point where making a prediction is now possible. For the first time in fire suppression history the potential for large fire behavior was predicted days prior to the event. It was known several days in advance that conditions were becoming very good for one or more large fire incidents to occur in the Northern Rockies prior to the Red Bench Fire run. In fact several fires had been designated as having the potential to make large fire runs during this time in 1988. This advanced warning, plus the advantages of good planning and improved communications undoubtedly saved lives and property. It is important to study major events such as the Red Bench Fire to improve our abilities for large fire prediction not just in the Northern Rockies, but throughout North America because the necessary conditions in one region may vary from those in another region. Probably the weakest link in the entire process is a lack of consistent Fire Danger and weather condition reporting from the many NFDRS stations nation wide. Stations with a poor reporting record not only impact the potential to evaluate current conditions but also leave the historical record incomplete from which future conditions will be compared to. Weather conditions tracked by these manually run stations is especially critical during late August through October and many stations historical data are especially weak during the September-October period. The replacement of manual recording NFDRS stations to RAWS and the automation of the data recording by computer will help to eliminate this problem area. With improved current and historical data bases our abilities to understand, and predict, extreme fire behavior events will improve even further.

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The 1988 Red Bench Fire: Documentation of Fire Behavior, Fire Weather, and Preburn Fuel Conditions in the North Fork of the Flathead River Valley.

1990

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Volume 2 - Appendices

Appendix A - Climatology

Introduction

In general the climate of the North Fork of the Flathead River in the vicinity where the Red Bench Fire occurred can be described as short, moist, summers with moderate temperatures and cool nights usually restricted to July-August; autumn (September-October) comes early and is distinctly a transitional season; winter (November-March) is normally a cold and very wet season; spring (April-June) is another transitional period with numerous cool, wet, stormy periods and doesn't seem to really arrive until shortly before summer. Shower activity during this spring period may be almost daily and is commonly mixed with snow, especially at the higher elevations surrounding the river valley. In most years, June will be the wettest month. The broken, mountainous topography of the area supports a continuum of climatic changes with differing combinations of altitude, slope, and aspect. The snow in the valley usually disappears between April and May, but may remain at the higher elevations until late July at elevations as low as 6,000 - 6,500 ft msl.

West of the Continental Divide of the Northern Rocky Mountains, Montana has a moderate and moist, maritime climate which is influenced more by air masses from the Pacific Ocean. East of the divide the climate is predominately influenced from the continental climate and experiences the extremes of summer heat and winter cold. The North Fork of the Flathead River valley which lies in a general north - south orientation is west of the Continental Divide but can be considered to be an area transitional between the Pacific maritime and continental weather types, on which there is superimposed the influence of mountain-climate characteristics. The Pacific influence is noted particularly by late autumn and winter maximum cloudiness and precipitation, with drier winters east of the divide. Also with the relatively moderate average temperatures compared to the continental type further east of the divide. Winter temperatures are especially variable on the Glacier National Park's east side of the Continental Divide, as arctic airflow alternates with warm, downslope winds (chinooks) occurring with Pacific air-flow. Summer is generally sunny and dry. July and August are the peak historic fire months, but may extended into fall during exceptionally dry late seasons. July is typically the driest month in Glacier National Park west of the Continental Divide, while further to the east on the adjacent plains October through March normally constitutes the dry season with July-September being transitional in terms of precipitation. Driest areas in the park are the northeast, and northwest corners (including the area around Polebridge).

Storms in the area generally track from the west or southwest following the prevailing flow aloft during both the summer and fall months. The main season of thunderstorm activity is between the period of mid-May to mid-September. During June through August these storms will occur with a frequency of between 15 and 20% of the days, or about an average of 5 days per month. Summer afternoon-evening thunderstorms commonly develop during periods of unstable atmospheric conditions and upper level moisture drawn from central-southern California. This flow pattern generally moves the thunderstorms across the Whitefish Mountain Range to the west of the North Fork of the Flathead River valley prior to the storms entering the river valley. Orographic effects commonly occur with the result that most storms result in precipitation and that dry lightning storms are unusual. Considerable amounts of lightning can occur however in these storms, and lightning caused holdover fires are frequently discovered following a short drying period. The lightning caused

fire season in Glacier National Park extends from May through October, with 98% of those fires between June 19th and Spetember 19%. The actual number of lightning caused fires is highly variable from one year to the next, ranging from zero to 38. The average annual number of fires caused by lighting between 1910 and 1968 was 10, while the median number was 8. During this time period 59% of the fires started within the park boundaries were ignited in the North Fork of the Flathead River drainage, 32% of these were Class C and larger fires. 50% of the lightning caused fires were started in the forests at or below 5,000 ft msl. Most of the lightning fires (69%) occur on southerly aspects (O'Brien 1969). Annual precipitation at the lower elevations in the region around the North Fork of the Flathead River ranges from about 15.4 inches to the west in Kalispell to 33.1 inches at the Hungry Horse Dam to the south. Within the North Fork of the Flathead River valley the Polebridge Ranger Station receives annually an average of 22.6 inches, and 28.7 inches in the Middle Fork of the Flathead River valley at Glacier National Park Headquarters in West Glacier. Along the Continental Divide to the east of the North Fork of the Flathead River valley the mountains may receive 100 inches or more annually (Finklin 1986).

To further describe in detail the climatology of the area around and within the North Fork of the Flathead River, individual National Weather Service (NWS) and National Fire Danger Rating System (NFDRS) stations will be used to characterize individual weather parameters. Polebridge, West Glacier, Hungry Horse Dam, and Kalispell are regular reporting NWS stations. Polebridge and West Glacier are NFDRS stations. The NFDRS data is collected once daily at 1400 hours usually from May through October at designated AFFIRMS weather stations, though the months will vary from station to station. Measurements taken for inclusion into the National Fire Weather Data Library (NFWDL) (Furman and Brink 1975) maintained by the USDA USFS Computer Center (FCCC) at Fort Collins, Colorado include; maximum and minimum daily temperature, relative humidity, dry and wet bulb temperature, wind speed, and 24 hour precipitation. Also several SNOWTEL sites are examined for snow water equivalent (SNOW) from near the river valley. SNOW data is collected at some locations twice monthly (1st and 15th of the month) but only data from the beginning of each month is examined. Stream flow data (STRM) from the North Fork of the Flathead River is examined to compare the 1988 stream gage measurements with the historical record. SNOW, STRM and NWS data bases are maintained for the region by the USDA SCS West National Technical Center (WNTC) at Portland, Oregon by the Snow Water Program and Water Supply Forecasting Staff.

Climatology Characteristics and Comparisons with 1988

POLEBRIDGE RANGER STATION, GLACIER NATIONAL PARK, POLEBRIDGE, MT

The Polebridge Ranger Station at latitude 48.46, longitude 114 16' (T35N, R21W, section 22) lies adjacent to, and on the east side of the North Fork of the Flathead River. The station is at an elevation of 3,520 ft msl and is approximately 2,325 ft below the origin point of the Red Bench Fire. This station is a NWS and NFDRS reporting site. During the late afternoon and evening of the second burning period on September 7, 1988 the Red Bench Fire burned through the ranger station. The station was abandoned prior to this fire run.

Precipitation

Water Year (October-September) precipitation ranges from 14.62 inches which occurred in 1977 to 35.09 inches in 1971. Average annual precipitation for the 42 year period (1947-1988) was 22.62 inches (Figure A-1, Table A-1). During this time period there has been a trend in declining annual precipitation, which was heavily weighted by dry Water Years from 1984-1988, and a period of above normal to average years at the beginning of the weather record. This 42 year trend indicates an approximate decline of -3.1 inches. During the 25 years between 1961 and 1985 the average annual precipitation was recorded at 22.63 inches, +0.01 inch above the 42 annual average. The 28 year period extending from 1965 through 1988 shows a declining trend of -0.53 inch (annual average 22.09 inches) illustrating the strong influence of the more recent dry years. After completion of the Water Year in September, the 1988 season ranked as the 41st driest year out of the 42 years of record. Only the 1977 Water Year was drier. The 1988 annual precipitation of 15.00 inches was estimated to have a return period of approximately 20 years.

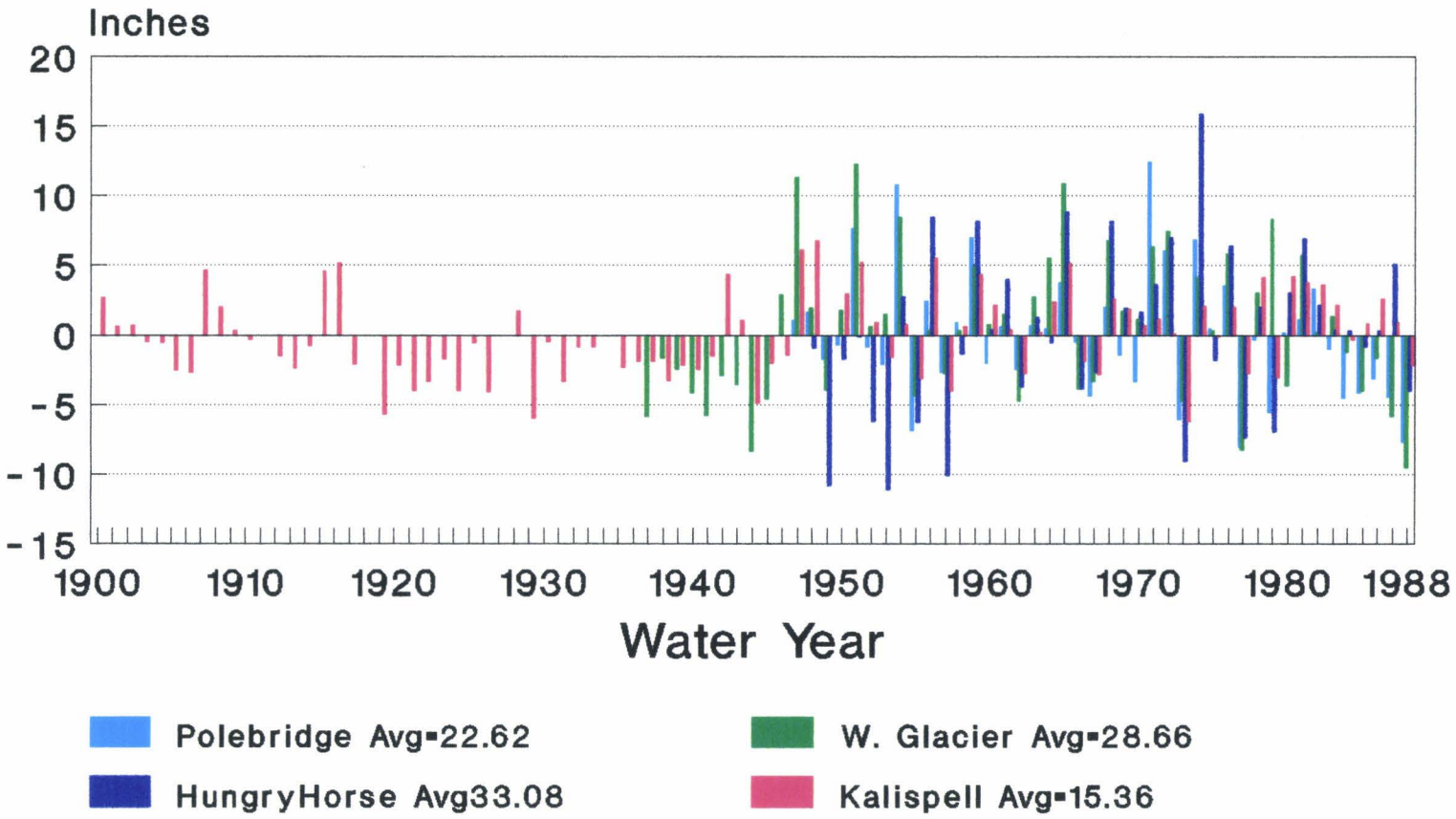
Prefire season precipitation, here defined as the October-May months had an average precipitation of 16.2 inches, and extremes of 8.35 inches in 1977 to 25.61 inches in 1971 (Figure A-2, Table A-2). The 1988 prefire season precipitation ranked as the 40th driest out of 42 seasons with 11.01 inches (Table A-3). The 1988 prefire season precipitation has been calculated to have a return period of between 5 and 10 years. March and May were the only 1988 prefire season months to have measured moisture greater than the monthly average, all other months were contributing to an increasing moisture deficit (NOAA 1988; NOAA 1989). During the historical record there has been a trend of declining precipitation of approximately -4.1 inches. During this period the trend has been strongly influenced by numerous dry prefire seasons in the preceding decade. Out of the prefire seasons between 1977 and 1988 there has been only two seasons with above normal precipitation. The decade of the 1950's and the first three quarters of the 1970's were exceptionally moist periods in the precipitation record from this station.

June-August precipitation is classified as fire season precipitation. June is included because of the apparent effect of dry weather during this normally very wet month in preconditioning fuel moistures. This season has received an average of 5.05 inches during a 43 year period of record (1946-1988) with extremes of 0.86 inches in 1967 (one of the previous most severe fire seasons within Glacier National Park) and 5.28 inches in 1971 (Figure A-3, Table A-4). The 1988 fire season ranked as the 42nd driest season out of the 43 year record with 2.36 inches, of which nearly 62% arrived during June (Table A-5). Only 1967 exceeded the low 1988 July-August precipitation amount when no measurable moisture was recorded at the Polebridge Ranger Station. The amount of fire season precipitation received in 1988 was calculated to have a return period of between 20 and 100 years. June through August continued to contribute to the moisture deficit as each month received less than the monthly average precipitation with August having the largest departure from normal, -1.10 inches (NOAA 1988; NOAA 1989). During the historical fire season precipitation record there has been a slight declining trend of -0.4 inches at this station.

Precipitation records for an extended fire season (June-September) from this station indicate an average of 6.40 inches with extremes occurring during the 1967 season with 0.95 inches (only 0.09 inches received in September) and 9.98 inches in 1951 (Table A-6). The extended fire season in 1988 ranked the 40th driest out of 43 seasons with 3.99 inches of moisture received with a return period of between 5 and 10 years (Table A-7). During the 1988 extended

Figure A-1. Water Year (October - September) difference from average precipitation totals for the Polebridge Ranger Station, Glacier National Park, Glacier National Park Headquarters (West Glacier), Kalispell airport, and Hungry Horse Dam.

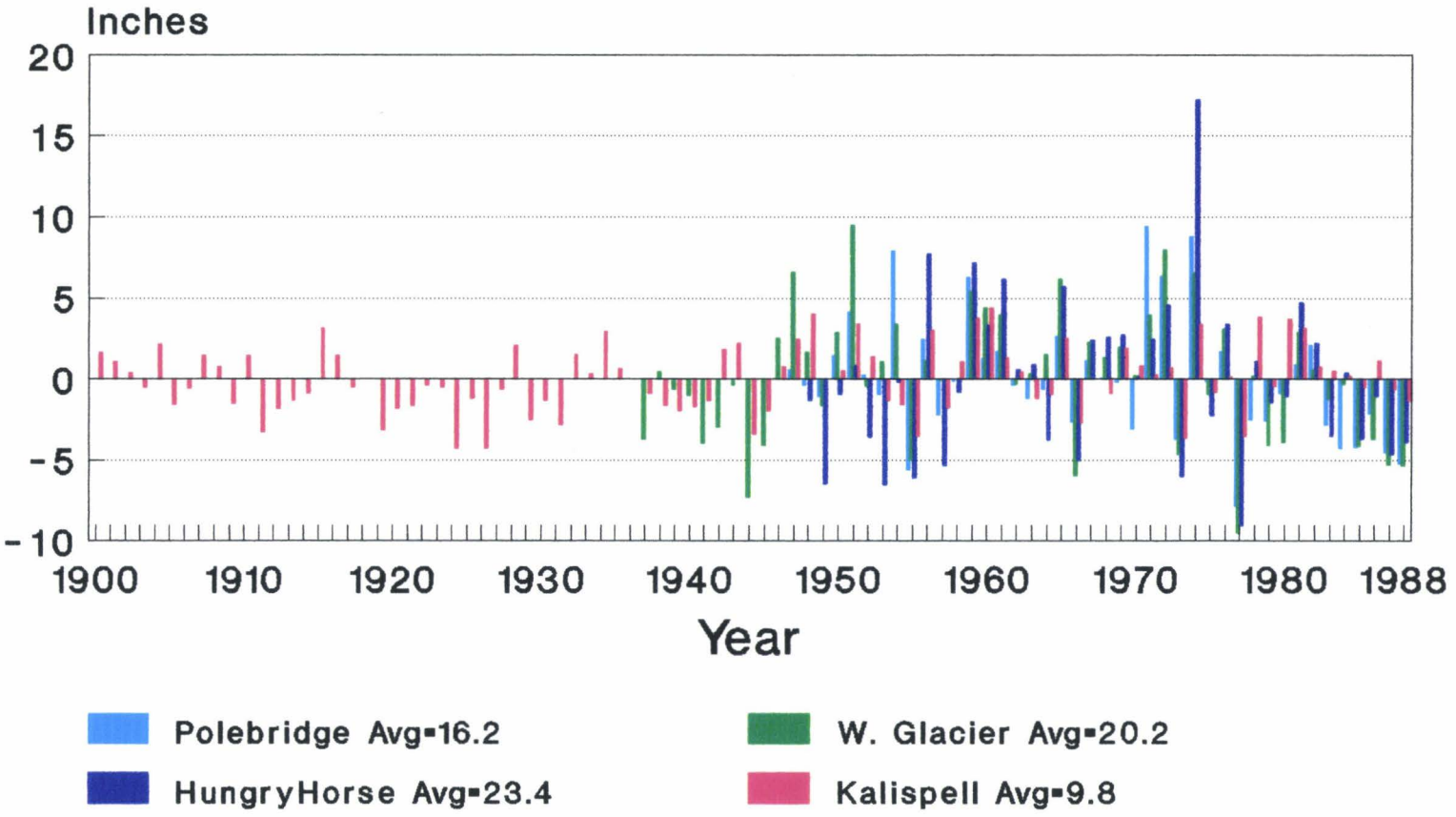
Water Year Precipitation
Difference from Average



Red Bench Fire (1988)

Figure A-2. Prefire season (October - May) difference from average precipitation totals for the Polebridge Ranger Station (Glacier National Park), Glacier National Park Headquarters (West Glacier), Kalispell airport, and Hungry Horse Dam.

October - May Precipitation
Difference from Average

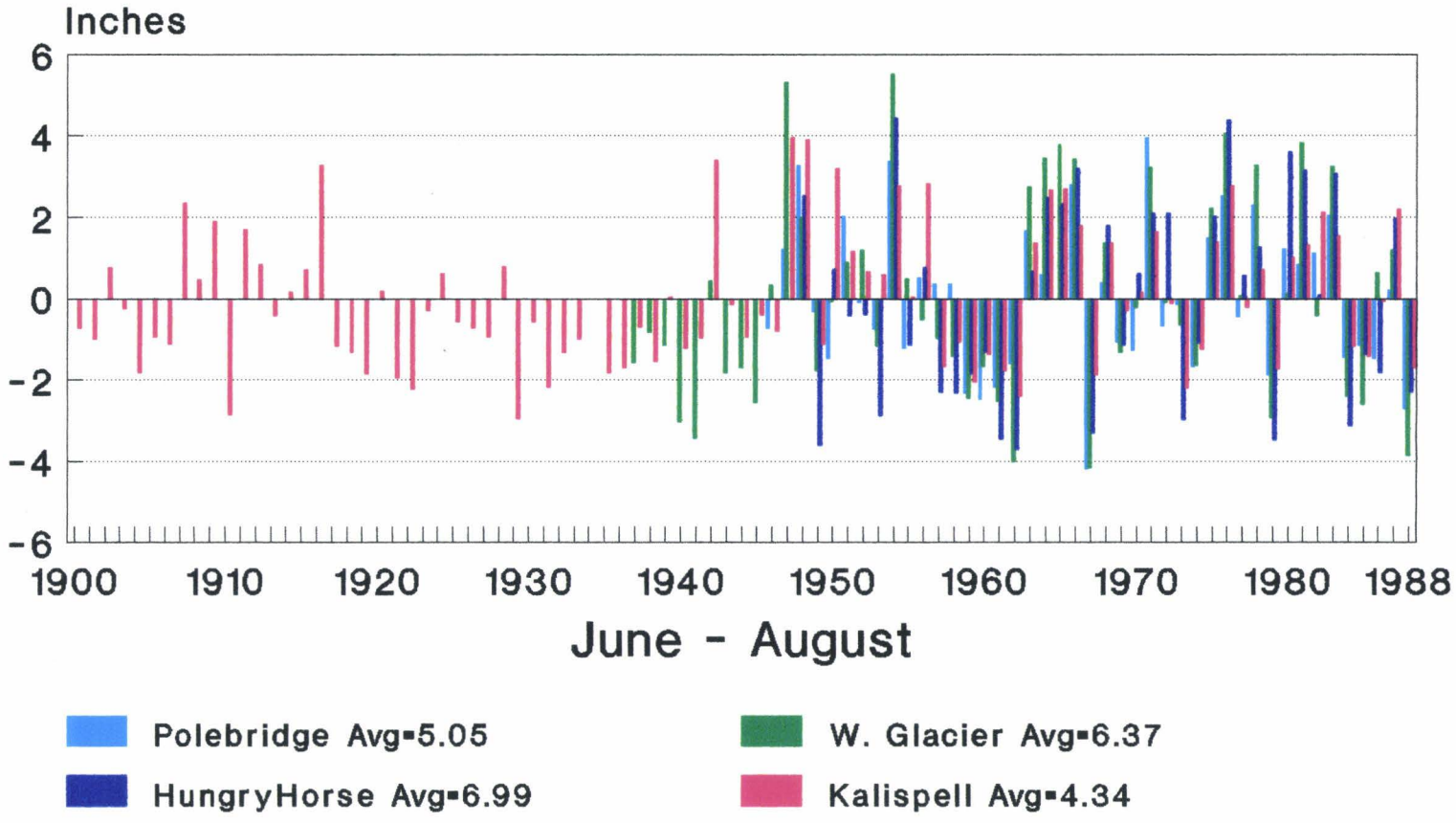


Red Bench Fire (1988)

Figure A-3. Fire season (June - August) difference from average precipitation totals for the Polebridge Ranger Station (Glacier National Park), Glacier National Park Headquarters (West Glacier), Kalispell airport, and Hungry Horse Dam.

Fire Season Precipition

Difference from Average



Red Bench Fire (1988)

fire season August received the least amount of the extended fire season precipitation (9.8%) while September received the greatest amount (40.8%). September was the first month since May to receive a moisture amount which exceeded the monthly average with +0.21 inches (NOAA 1988; NOAA 1989).

This station during the month of June has an average of 16-17 days (55.5%) during which it will receive 24 hour precipitation totals of 0.1 inch or greater. Eleven days (36.7%) will average 0.2 inches or greater moisture during a 24 hour period. These values are based on a record of 314 days over a 20 year period, or only 52% of the potential record of 600 days for the month of June. During July an average of 10 days (32.7%) will receive a 24 hour precipitation total of 0.1 inch or greater, and 6 days (18.3%) with 0.2 inch or greater (based on 935 days over a 36 year period, or 83.7% of the potential total for the month). August experiences an average of 11 days (36%) with 24 hour precipitation totals of 0.1 inch or greater, and also 6 days (20.9%) with 0.20 inch or greater (978 days over 37 years, or 85.2% of the monthly potential total record). Nearly half of the month of September (14 days, 45.2%) averages 0.1 inch of 24 hour precipitation. About 8 days (25%) receives 0.2 inch during a similar time period on the average (based on 425 days over a 32 year record, a 44.2% of the potential record days).

Temperature

The last killing frost (28F or lower) at the Polebridge Ranger Station has a 50% probability of arriving later than June 8th, and a 10% probability of arriving later than June 27th (Table A-8). The first killing frost of the fall has a 50% probability of arriving earlier than August 31st, and a 10% probability of arriving before August 17th.

The average annual temperature is 39.1F (based on 1948-1988 records), with an average maximum temperature of 53.4F and a minimum average temperature of 24.7F. July experiences the warmest average daily maximum temperatures of 79.5F, followed by August with 78.9F. These two months also have the respective warmest average daily minimum temperatures of 40.5F and 39.1F. The extreme daily maximum temperature recorded was 103F in 1960. There is a 20% probability that during the month of July a temperature of greater than 95F will be achieved, and during August a temperature greater than 94F.

The highest monthly mean maximum daily NFDRS temperatures also were recorded in July (82.0F), with the extreme average measurement occurring in 1960 (93.7F). July was closely followed by August in this category, with a monthly mean maximum daily NFDRS temperature of 81.0F, and the extreme average being recorded in 1967 with 92.6F. The 10-day period beginning July 21st has the highest mean maximum daily NFDRS temperature of 85.2F. Mean maximum daily NFDRS temperatures above 70F for 10-day periods can occur at any time between June 11th and September 21st. For mean maximum daily NFDRS temperatures greater than 80F the period is between July 11th and August 21st. Extreme maximum daily NFDRS temperatures greater than 90F have occurred during the 10-day periods between June 21th and September 21st, extreme temperatures of 100F or greater between July 11th and September 11th. Temperatures of 100F or greater have infrequently been measured at this station, only during 5 years of the 33 year temperature record between 1954-1988 (the years 1955 and 1971 have no data from this station). The 1988 season did not establish any NFDRS records for single day, 10-day, and monthly period means or extreme high/low maximum temperature readings at the Polebridge Ranger Station.

The lowest monthly extreme minimum NFDRS temperatures at this station between May and October range from 14F-27F, indicating that below freezing

temperatures may occur at any time of the year. Mean 10-day period minimum NFDRS temperatures climb above the freezing mark May 21st (33.4F), peak during the period beginning July 11th (41.2F), and remain above freezing until the seasonal records end on October 11th (33.0F). The 1988 season did not establish any NFDRS records for single day, 10-day, and monthly period means or extreme high/low minimum temperature readings at the Polebridge Ranger Station.

The monthly mean NFDRS temperatures during the extended fire season range from 33.2F during September to 41.0F in July. NWS daily mean temperatures have a similar pattern ranging from 50.1F during September to 60.0F in July. The 1988 season did not establish any NFDRS records for single day, 10-day, and monthly period means or extreme high/low mean temperature readings at the Polebridge Ranger Station.

Departures from average monthly temperatures at this station during the 1988 Water Year was not nearly as great as at other NWS reporting stations in this portion of the Northern Rocky Mountains (NOAA 1988; NOAA 1989)(Figure A-4)(see Headquarters, Kalispell, and Hungry Horse Dam climatology sections). The month of October was the first of seven months at this station which would have monthly temperature departures from average below the normal during the Water Year. November was a warmer than normal month with a +2.8F departure from the average. December through February were cooler than normal with -2.1F, -1.2F, and -0.4F respectively. With the arrival of March early spring temperatures started to climb with the largest departure from normal which would be measured during the Water Year at this station, +4.3F. April continued to stay warm with +3.8F above the monthly average. May temperatures dropped slightly below normal (-0.4F). The month of June experienced a return to above normal temperatures with a +3.0F departure from average. The normally warm months of July and August saw a return to slightly cooler than normal temperatures, -1.4F and -0.5F respectively. September was the start of an unseasonably warm autumn with temperatures +0.7F above average. October temperatures climbed to +4.5F above average, while November still found the Red Bench Fire smoldering and temperatures of +2.9F above the normal for that month.

Relative Humidity

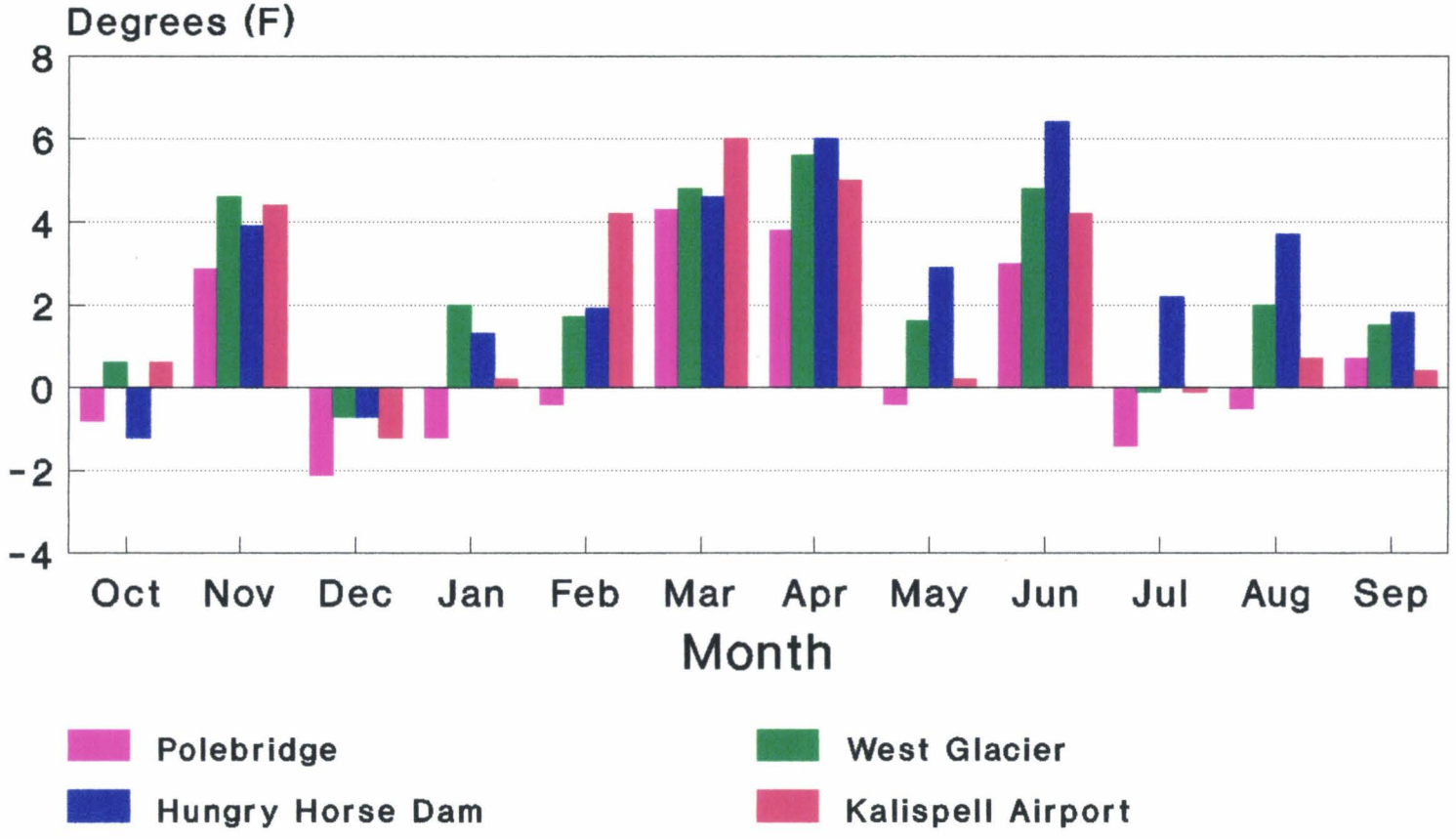
The NFDRS records for relative humidity from this station are insufficient to establish any 10-day, or monthly period trends or patterns.

Winds

NFDRS winds during the extended fire steadily increase in average wind speeds starting in June with 3.6 MPH through September with 4.8 MPH. August has the greatest variability of average wind speeds and direction, ranging from 1.3 MPH out of the southeast to 6.5 MPH from the northwest (does not include calm periods). During June NFDRS winds of 8-12 MPH occur with a frequency of 8.2%, 13-18 MPH 0.7%, 19-24 MPH 0.4%. July NFDRS winds occur between 8-12 MPH with a frequency of 14.3%, 13-18 MPH 2.3%, no data for between 19-24 MPH, and wind speeds >24 MPH a frequency of 0.2%. NFDRS winds for August indicate 16.4% of the readings falls between 8-12 MPH, 13-18 MPH 2.5%, no data for between 19-24 MPH, and only 0.1% for >24 MPH. September NFDRS wind speed measurements have 18.3% within the 8-12 MPH range, and 3.4% between 13-18 MPH with no greater wind speeds recorded. Only the months of July and August had wind speeds in excess of 24 MPH recorded from this station.

Figure A-4. 1988 Water Year differences from average of the monthly average temperatures from the Polebridge Ranger Station (Glacier National Park), Glacier National Park Headquarters (West Glacier), Kalispell airport, and Hungry Horse Dam.

Average Monthly Temperatures
1988 Water Year Differences from Average



Red Bench Fire (1988)

3-Way Co-occurrence of Extreme Burning Conditions and the Rxburn Program

A close examination of the weather conditions during periods of extreme burning conditions when fires in the Northern Rocky Mountains (principally NFFL Fuel Models 9 and 10) started to exhibit running crown fire behavior was made. these fires included prescribed fires within the Bob Marshall Wilderness complex, as well as wilderness wildfires and wildfires on the Flathead National Forest, Idaho Panhandle National Forest, and Glacier National Park. It was found that these fires commonly had temperatures 75F or greater, relative humidities of 25% or less, and minimum 20 ft wind speeds of approximately 9 MPH when the fires started to exhibit crowning behavior. If temperatures climbed to 80F with the same relative humidities and minimum wind speeds crown fireswere usually well developed. Crown fire behavior could be maintained with lower temperatures and rising humidities if during a frontal passage strong winds persisted or strengthened. To determine the number of days when these minimum conditions were attained at AFFIRMS stations in the NFDRS, the "prescription" window was completed to include the potential extreme or hot side of the prescription. Temperatures of 95F, RH's of 1-10% (lowest classification) for the program 3-way and 5% for the Rxburn program, and 25 MPH for wind speed were used. None of the fires examined occurred during these extreme hot, dry prescription conditions. Most crown fires occurred between 75F-80F, 15-25% RH, and 9-20 MPH wind speeds. It should be noted that these programs are for weather data analysis, as a result fuel moistures do not enter into the prescription. Prescription days may in reality be eliminated if fuel moistures are too high. Also the NFDRS weather collected at 1400 hours does not always represent the fact that the prescription may have been attained later in the day, in this respect the number of days of prescription attainment may be under estimated slightly. The analysis also does not take in to account the fact that a fire may not be burning on a day within prescription, or that a fire which is burning has insufficient fuel or an effective barrier to prevent spread. Another limitation is the limited historical base for fire weather records, as well as the fact that there may be both individual days as well as even years missing from the data base of a particular station. And in case any of us forget, individual weather events do not follow any statistical description, these numbers only help us to try and understand the occurrences. There is no statistical reason why an event that we might rate as occurring once every 20 years based on the limited historical record, can not occur during consecutive years, or for that matter twice within a period of even shorter duration.

A close examination of the weather window of 75F-95F, 1-30% RH, and 5-20> MPH wind speeds for the months of June through September by the 3-way program for the Polebridge Ranger Station shows July and August with the highest frequency of occurrence. The period of data examined included a maximum of 34 years of records (1954-1988, minus 1971) for the 10-day periods between August 11th and September 1st, to only 10 years of records for the 10-day period beginning September 21st. June data showed that the above weather prescription combination with wind speeds between 5-9 MPH occurred with a frequency of 8.2%, 10-14 MPH a frequency of 0.4%. June data with wind speeds of 15 MPH or greater were out of prescription. July frequency of occurrence for data with wind speeds of 5-9 MPH was 16.1%, and with the temperature raised to 99F an additional 0.5% of the data has historically occurred. July wind speeds of 10-14 MPH combined with the rest of the prescription window had a frequency of 4.1%, and with the temperature raised to 99F an additional 0.1%. July wind speeds of 15-19 MPH were in prescription with a frequency of 0.7%, and with

winds of 20 MPH or greater a frequency of 0.1%. The month of August had a frequency of occurrence with the original weather window and 5-9 MPH wind speeds of 17.3%, and expanding the window to include up to 99F temperatures added another 0.3%; with 10-14 MPH an occurrence of 4.4% (expanded to 99F, an additional 0.4%); 15-19 MPH an occurrence of 0.9% (expanded to 99F, an additional 0.1%). After the frequency of days within prescription peak in August there is a decline in September, principally at the higher wind speeds. September frequency of occurrence with 5-9 MPH wind speeds was 15.1%, 10-14 MPH drops to 1.4% (expanded to 99F, an additional 0.2%), and 15-19 MPH an occurrence of 0.4% (expanded to 99F, an additional 0.2%).

An examination of a more restrictive weather window covering 3,049 days during May through October over 37 years (1951-1988) was accomplished with the Rxburn program. The preferred prescription of 80-95F, 5-20% RH, and 9-25 MPH wind speeds for weather during which crown fires were well developed had only a 3% occurrence, or a total of 83 days out of the 3,049. August had the highest percentage of the 83 days with 56.6% (47 days); while in declining order occurred July with 32.5% (27 days), September with 9.6% (8 days), and June 1.2% (1 day). In terms of the entire fire weather record this translates to 2.7%, 0.9%, 0.3%, and 0.03% for each month respectively. No days in either May or October meet the preferred prescription requirements. Another method of interpreting these results is an estimated return interval based on the number of years it would take for a single day in any particular month to be within prescription. This estimated return interval will be calculated using the actual data and not a return interval based on a statistical distribution, such as the return period of a particular Water Year. In chronological sequence it would take June 10.5 years to have 1 day in the preferred prescription (based on a limited June data base), July would have 1 day each 1.3 years, August 1 day each 0.7 years, and September would have 1 day each 2.1 years (again a limited data base).

An Rxburn program with an acceptable (parameters having a greater range) prescription illustrating the period of starting crown fire behavior of 75F-95F, 5-25% RH, 9-25 MPH had a 2% occurrence (51 days) out of a total of 3,049 days of data. July this time had the highest percentage of days within this prescription window, 43.1% (22 days) followed closely by August with 41.1% (21 days), September 11.8% (6 days), June and May each had 1.9% (1 day). in terms of the entire fire weather record for the Polebridge Ranger Station the days meeting the acceptable prescription were 0.7%, 0.7%, 0.02%, 0.03%, and 0.03% for each respective month. The estimated return interval for each month in chronological order would be 2.1 years for 1 day in May (based on a very limited and tenuous data base), June would have 1 day every 10.5 years (again a limited data base), July will experience 1 day every 1.6 years, August 1 day each 1.7 years, and September 1 day each 2.8 years (limited data base).

Snow Water Equivalent

The nearest SNOWTEL measuring station to the Polebridge Ranger Station in the North Fork of the Flathead River valley is located at Kishenehn nearly 14 miles to the north-northeast (latitude 48 58', longitude 114 25'; T37N, R22W, section 14). This low elevation station, 3,890 ft msl, is only measured during March and April. Both months during 1988 the snow water equivalent was considerably below the historical average of 43 years of record keeping (1946-1988)(Figure A-5, Table A-9). Only two March measurements were lower than the March 1988 snow water equivalent. Five April measurements had been lower than that collected in April 1988.

HEADQUARTERS, GLACIER NATIONAL PARK, WEST GLACIER, MT

Glacier National Park Headquarters, just outside West Glacier, MT is within one-half mile of the Middle Fork of the Flathead River at latitude 48.30, longitude 113 59' (T32N, R19W, section 26). The station is at 3,154 ft msl, 366 ft lower than the Polebridge Ranger Station and 2,691 ft below the origin point of the Red Bench Fire. Park Headquarters is approximately 4.7 miles northeast of the confluence of the North and Middle Forks of the Flathead River, and about 23.5 miles south - southeast of the Polebridge Ranger Station. This station is both a NWS and NFDRS reporting station.

Precipitation

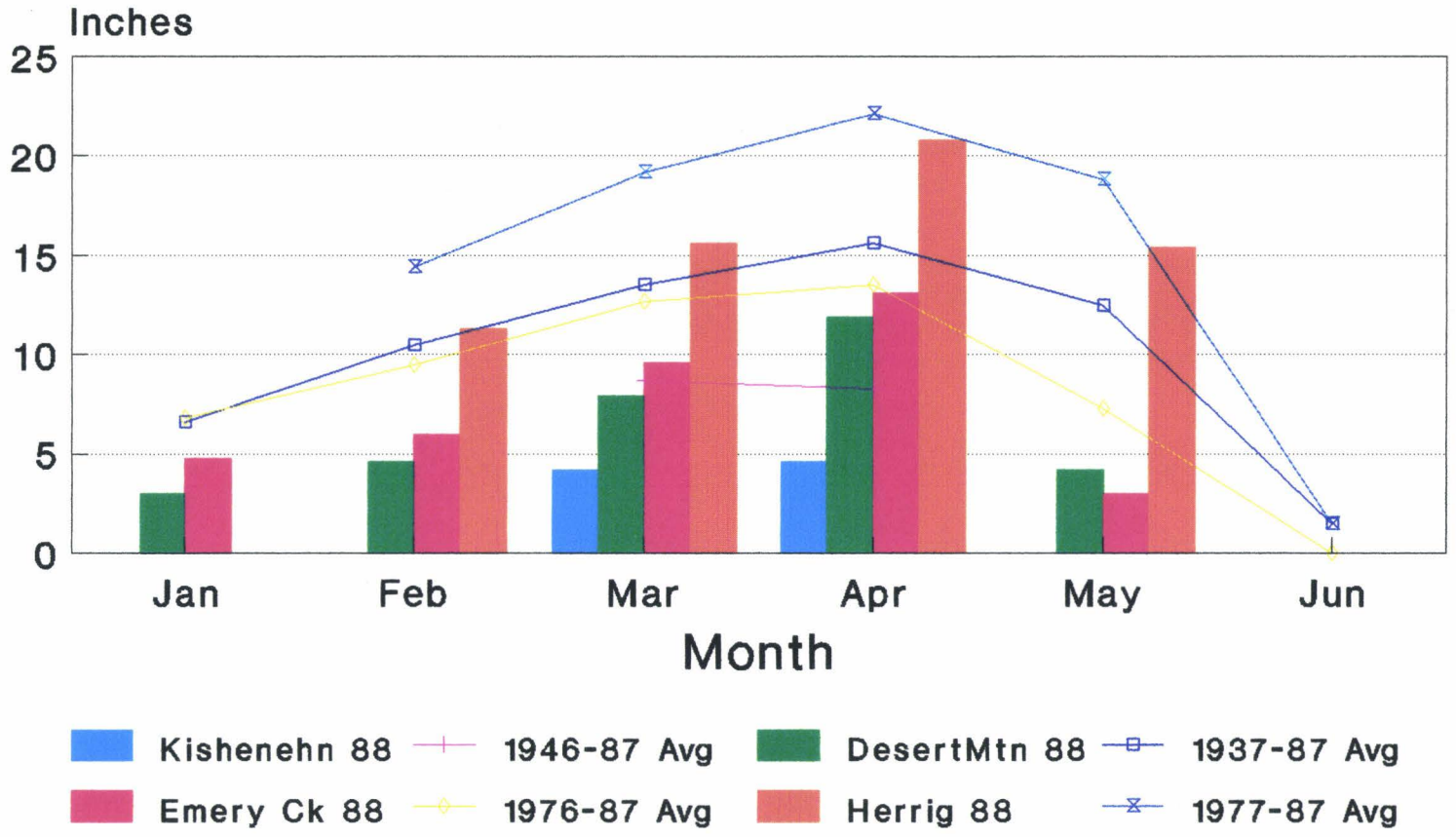
Records for precipitation have been maintained at this station since 1937, 52 years, with an average Water Year precipitation of 28.66 inches and ranges from 19.19 inches in 1988 to 40.94 inches in 1951 (Table A-10). There has been a slight increasing trend in average Water Year moisture received at this station, +0.8 inches. During the 25 year period of 1961-1985 the trend was also an average +0.91 inches during that period above the longer term historical average. Extending the period to include the 28 years prior of 1961-1988 there is still a positive trend, but only +0.20 inches, the change resulting from three consecutive Water Years of below average precipitation culminating in the record dry 1988 Water Year at this particular recording station. As noted above the 1988 Water Year at the Headquarters station was the driest year in 52 years of record keeping, with a calculated return period of between 20 and 100 years. Most years in this record are relatively close to the average precipitation, with above average years usually a slightly greater difference from average than below average years. Only during the late 1930's and early 1940's was a prolonged drying trend as strong and persistent as the 1986-1988 record.

Prefire season precipitation averages 20.20 inches for the 52 years of October-May records, with extreme ranges of 10.74 inches received in 1977 and 29.68 inches in 1951 (Table A-11). The 1988 prefire season was ranked as the 49th driest season on record (14.85 inches) with a return interval of between 10 and 20 years (Table A-12). May was the only prefire season month at this station to receive greater than the monthly average moisture, +2.18 inches. All other months contributed to a steadily increasing moisture deficit (NOAA 1988; NOAA 1989). There has been a slight declining trend of -0.3 inches of precipitation over the record of this season. The prefire seasons from 1946-1976 off set the general dry periods experienced from 1937-1945 and 1977-1988. How long the pre-1937 drought conditions may have existed at this site is unknown, nor if the current dry period being experienced will continue with occasional near average seasons.

Fire season precipitation has averaged 6.37 inches over the 52 years of record, with extreme ranges of 2.22 inches collected during 1967 (an extreme fire season year) and 11.89 inches in 1954 (Table A-13). 1988 June-September fire season was ranked as the 50th driest season (2.51 inches) at this location with a return interval of between 10 and 20 years (Table A-14). June of the 1988 season received 76.8% of the total fire season moisture, similar to the 87.4% the fire season moisture the month of June received during the record 1967 season. The percentage of fire season moisture received in June is not necessarily unusual. However what does separate these seasons from other less severe years is the fact that these June months received an appreciably small

Figure A-5. 1988 difference from average snow water equivalent from stations located at Kishenehn (Glacier National Park), Desert Mountain (Flathead National Forest), Emery Creek (Flathead National Forest), and Herrig Junction (Montana Department of State Lands).

1988 Snow Water Equivalent
Difference from Average



Red Bench Fire (1988)

amount of moisture to begin with, followed by a continued critical lack of moisture during July and August. There has been an trend of increasing moisture received at this station over the fire season record, an increase of about +2.2 inches. This trend appears to be a response to a more random distribution of wet / dry fire seasons following a period of fire seasons with mostly below average precipitation from 1937-1962. During that 26 year period only 8 seasons received greater than normal moisture.

Extended fire seasons including the month of September have averaged 8.46 inches with extreme ranges of 2.92 inches in 1967 and 13.91 inches measured in 1968 (Table A-15). 1988 was ranked as the 49th driest extended fire season (5.29 inches) out of a record of 52 seasons with a return period calculated to be between 5 and 10 years (Table A-16).

During the month of June at the Headquarters Station there may be expected on the average 21 days (68.9%) with 0.1 inch or greater precipitation, and 14 days (45.5%) will receive 0.2 inch or greater. Similar precipitation totals for the month of July indicate that there will average 15 (47.7%) and 10 (31.5%) days respectively. During August, the driest month of the Water Year, will have a greater number of days with precipitation totals of 0.1 and 0.2 inch than July on the average; 15 days (47.7%) and 10-days (31.5%) respectively. July usually has a greater number of precipitation events of 0.8 inch or greater than August which accounts for August having the reduced monthly average.

Temperature

The last killing spring frost at Park Headquarters, West Glacier has a probability of arriving 50% of the time later than May 13th, and 10% of the time later than May 30th (Table A-17). The first killing frost of the winter season has a 10% probability of arriving earlier than September 12th, and a 50% probability of being earlier than September 26th. this station has an average annual temperature of 41.9F (based on a record from 1950-1988) and an annual average maximum of 52.9F. The month of July has the greatest average daily temperature of 63.0F, and the highest average daily maximum temperature of 79.2F. August follows July as a close second in both values; with 61.9F and 77.8F respectively. Maximum daily extremes of 102F have been recorded in July of 1979, and again in August of 1981. July has a 20% probability of achieving at least one day during the month of a daily maximum temperature of 93F or greater. August has the same probability of reaching 92F or greater. Similar probabilities exist for June attaining 89F or greater, and September of 86F or greater.

The highest monthly mean maximum NFDRS temperatures at this station also occurs during July (80.9F) and August (79.7F) with the extreme monthly average temperature of 90.5F occurring in July 1985. The 10-day period mean maximum NFDRS temperature high occurs during the period beginning July 21st, 84.0F; which is slightly higher than the following 10-day period beginning August 1st with 83.2F. During 1988 a record mean maximum 10-day NFDRS temperature was established during the period beginning on July 21st of 90.7F at this station. Also during 1988, this station achieved a new record mean maximum monthly NFDRS temperature for the month of June with 79.4F. No NFDRS temperature records for 10-day, or monthly extreme temperatures were established during 1988. Maximum daily NFDRS temperatures of 70F or greater can be expected to occur anytime during the May through end of October NFDRS record keeping period. Temperatures of 80F or greater have been recorded from May 1st through the September 21st 10-day period. The principal period of temperatures of 90F or

greater occurs between July 11th and September 10th, but have been recorded as early as the 10-day period beginning May 21st. Temperatures between 95F to 99F occur between July 21st and August 31st. Temperatures of 100F or greater have been measured during the last half of July and the last 10-day period of August beginning August 21st. Only 0.5% of the maximum NFDRS temperature measurements between the years 1964-1988 for the month of July are for temperatures of 100F or greater, and for the month of August only 0.2% of the measurements. Temperatures of this extreme range are very unusual during the summer months.

July has the highest monthly mean minimum daily NFDRS temperature (47.8F), followed by August (46.6F) and June (44.4F). During 1988 the month of June established a new record for the highest mean minimum NFDRS temperature of 47.7F. This record and the one achieved for the highest mean maximum NFDRS temperature during the same month illustrates how unusual and warm June 1988 was during the early part of the fire season. A record extreme low 10-day NFDRS temperature was also recorded during the period beginning September 1st of 1988 with a measurement of 28F following the dry-cold front passage which contributed to the rapid spread of the Red Bench Fire.

The highest monthly mean NFDRS temperatures, as expected occurs during July (64.4F) followed closely by August (63.1F). During the 1988 season the month of June established a new record monthly mean NFDRS temperature of 63.5F. The two 10-day periods covering the dates from June 11th through June 30th achieved new record 10-day mean NFDRS temperatures of 63.8F and 67.9F respectively. During the same two 10-day period record extreme NFDRS temperatures were reached of 74F and 78F respectively. A record high mean daily NFDRS temperature for the month of June was established in 1988 with the 78F. These values further illustrate the unusually warm temperature being reached for that particular time of the year.

Nearly all of 1988 Water Year would be measured as exceeding the individual monthly average temperatures at this station (NOAA 1988; NOAA 1989). October started with only a +0.6F departure from normal which climbed in November to +4.6F. A return to slightly below average temperatures was recorded in December with -0.7F. January and February saw nearly identical departures from average with +2.0F and +1.7F respectively. March and April spring temperatures were quite warm for the season with departures of +4.8F and +5.6F from average. May temperatures were still warm, but closer to average with only a +1.6F departure. June temperatures again returned to very warm, eventually being measured with +4.8F departure from average. The normally warm month of July was the closest month to the average monthly temperature, -0.1F, during this Water Year. August through September again returned to above normal temperatures to close out the extended fire season with departures from average of +2.0F, +1.5F, respectively. As the Red Bench Fire continued to smolder in October and November temperatures stayed unseasonably warm with departures from average of +3.4F and +3.5F.

Relative Humidity

Maximum NFDRS relative humidities of 100% can be achieved at any time during the NFDRS record period of May 1 through October 31st. Low maximum NFDRS relative humidity measurements of below 30% are restricted to the record of the 10-day period beginning September 1st.

September is the month with the lowest monthly mean minimum NFDRS relative humidity (27.9%) followed by May (31.0%), and then July (31.5%). The normally moist month of June has the highest monthly mean minimum NFDRS relative humidity (36.3%). From May 1st through September 30th the relative humidity

has achieved historical extreme low readings of 12% or less. NFDRS minimum relative humidity readings of 5-9% have occurred in July with a frequency of 0.3%, August 1.0%, and September 0.3%. Readings in the range of 10-14% have monthly frequencies of 8.2% in May, 2.3% in June, 4.2% in July, 6.0% in August, and 6.3% in September.

September has the lowest monthly mean NFDRS relative humidity of 62.0%, followed by May with 62.7%. July and August follow these two end of the fire season months with monthly mean NFDRS relative humidities of 63.7% and 64.5% respectively.

Winds

NFDRS winds during the extended fire season average between 6.0 and 6.3 MPH with the greatest variability of range occurring during the month of August (average 5.0 MPH from the northeast to 7.0 MPH from the southwest, does not include calm periods). During June NFDRS winds of 8-12 MPH occur with a frequency of 26.7%, principally out of the southwest (13.9%); winds of 13-18 MPH 4.4%, principally out of the southwest (2.2%). No NFDRS wind speeds in excess of 18 MPH have been recorded during June. July NFDRS winds between 8-12 MPH occur with a frequency of 24.3%, of which 14.1% is from the southwest; wind speeds of 13-18 MPH occur with a frequency of 6.6% with 4.2% from the southwest; winds of 19-24 MPH occur only 1.3% of the measurements and have only been measured from the southwest. No wind speeds in excess of this last wind speed class have been recorded during July. August NFDRS wind speeds of 8-12 MPH occur with a frequency of 23.4% and usually (14.5%) from the southwest; speeds of 13-18 MPH have a frequency during the month of 6.3% of which 4.4% of the measurements are from the southwest; only 0.1% of the readings fall in to the 19-24 MPH class, and another 0.1% in the greater than 24 MPH wind speed class with these readings occurring from the southwest. NFDRS September wind speeds of 8-12 MPH occur with a frequency of 23.3% of which 13.3% are out of the southwest; speeds of 13-18 MPH have a frequency of occurrence of 4.4% with 3.0% of that total from the southwest; 0.6% of the wind speed measurements for this month are in the 19-24 MPH class and all from the southwest; no measurements in excess of 24 MPH are on record.

3-Way Co-occurrence of Extreme Burning Conditions and the Rxburn Program

An examination of the prescription window used with the 3-way program analysis of this stations AFFIRMS data of 75F-95F, 1-30% RH, and 5-20> MPH wind speeds for the months of June through September show August then July as having the greatest frequency of occurrence. The period of data examined included up to 23 years between 1960-1988. June data showed that the above combination with wind speeds of 5-9 MPH occurred with a frequency of 5.7%, 10-14 MPH had a frequency of 2.2%, 15-19 MPH a frequency of 0.4%. June data with wind speeds of 20 MPH or greater did not occur. July frequency of occurrence for data with wind speeds of 5-9 MPH was 13.7%, 10-14 MPH was 3.9%, 15-19 MPH was 1.3%. July measurements with wind speeds of 20 MPH or greater were not in the prescription, if the temperature window of the prescription was expanded to include 70F-74F a frequency of occurrence of 0.1% is present. If a crown fire was already in progress following a dry-cold frontal passage and temperatures were falling, wind speeds of 24 MPH or greater could sustain the fire behavior at these lower temperatures. The month of August had a frequency of occurrence with the original prescription window and 5-9 MPH wind speeds of 14.4%, 10-14 MPH was 6.1%, 15-19 MPH 1.7%, and wind speeds of 24 MPH or greater was 0.1%

occurrence in prescription. Expanding the prescription for the last wind speed class did not increase the frequency of occurrence. September frequency of occurrence declined in all wind speed categories except for the 24 MPH or greater class which increased. Occurrence in the 5-9 MPH wind speed class was 3.9%, 10-14 MPH was 2.6%, no observations were in prescription in the 15-19 MPH class, and 0.3% in the 20 MPH or greater wind speed class. For this last class of 20 MPH or greater this was the highest frequency of occurrence of any month during the extended fire season.

An examination of more restricted windows covering 2,721 days over 27 years of fire seasons was accomplished with the Rxburn program. The preferred prescription of 80F-95F, 5-20% RH, and 9-25 MPH wind speeds had a 1% occurrence, or a total of 33 days. August had the greatest percentage of the 33 days with 57.6% (19 days); while in declining order occurred July 30.3%, September 9.1%, and June 3.1%. In terms of the entire fire weather record examined for this station this translates in to frequencies of 0.69%, 0.31%, 0.11%, and 0.03% for each of the respective months. In chronological sequence the calculated return interval for 1 day meeting prescription in June is 18.5 years, every 2.3 years for July, every 1.2 years in August, and 4.1 years for September.

An Rxburn program acceptable (parameters have a greater range) prescription of 75F-95F, 5-25% RH, and 9-25 MPH wind speeds had a 2% occurrence (65 days)out of the total 2,721 days of data. August again had the greatest percentage of days within this window with 38.5% (25 days). This was followed by July with 35.4%, September with 9.2%, and June with 7.7%. Again, in terms of the entire fire season weather record the days meeting the acceptable prescription were 0.92%, 0.85%, 0.22%, and 0.18% respectively. The calculated return interval for the 1 day in the acceptable prescription in chronological order is 3.7 years for June, every 0.98 year in July, 0.89 year in August, and every 2.0 years in September. No days in October fell within the acceptable prescription window parameters.

Snow Water Equivalent

The SNOWTEL measuring stations at Desert Mountain and Emery Creek are the nearest stations measuring snow water equivalent to the southern end of the North Fork of the Flathead River valley. The Desert Mountain station is located at about 5.5 miles to the south-southeast of Park Headquarters (latitude 48 25', longitude 113 57'; T31N, R18W, section 30). This high elevation station, 5,600 ft msl, is only measured from January through June. During the first five months of 1988 the snow water equivalent was considerably below the historical average of 20-52 years (depending on month) of record keeping (1937-1988)(Table A-18). May 1988 measurements were -10.2 inches lower than the historical snow water equivalent for the same period. Between April and May the snow water equivalent had declined by 64.7%, normal decline for this period is only 20.0%. No snow was measured by the 1st of June which is a relatively common occurrence. It appears from the data that if the measurements are low in May, no data is collected in June.

The Emery Creek station lies at the head of Emery Creek about 1.5 miles northeast of the Desert Mountain station (latitude 48 26', longitude 113 51'; T31N, R18W, section 20). This is a mid elevation station at 4,350 ft msl and is also measured January through May. All five months are below the historical average for this station as well (9-13 years, depending on month)(Table A-19). The month of April was only -0.6 inches below the average (13 years, 1976-1988). May snow water equivalent dropped rapidly from the April

measurement resulting in -4.0 inches departure from normal. This was a decline of 77.1% between April and May, the normal decline is 48.9%. No snow was measured in June, and evidently never has been.

Stream flow of the North Fork of the Flathead River

Stream flow of the North Fork of the Flathead River at the gaging station north Columbia Falls and west of West Glacier (latitude 48 30', longitude 114 08'; T32N, R20W, section 35) results from precipitation received in the watershed defined by the east slopes of the Whitefish Range and the west slopes of the Livingston Range extending north in to British Columbia, Canada. Stream flow measured at this gaging station was slightly below average during the 1988 Water Year months of October through March (Figure A-6, Table A-20). Beginning in April the flow was slightly greater than normal due to the snow melt resulting from warm spring temperatures. The month of May is historically the month of peak flow and in 1988 was well below normal. Historically June is only slightly below May in flow. In 1988 June was considerably below both the historical average for the month as well as the previous 1988 May measurement. This early decline was the combined result of early melt off depleting the lower than average snow water equivalent in the snowpack of the surrounding mountains. The months of July through September would continue to have lower than average stream flow due to greater than normal June temperatures causing an increase in evapotranspiration, as well as below normal precipitation from June through August. Stream flow in the North Fork of the Flathead River during the 1988 Water Year was ranked as the 55th lowest in a historical record of 58 years (1911-1988) with a calculated return interval of between 10 and 20 years (Table A-21).

KALISPELL, MONTANA

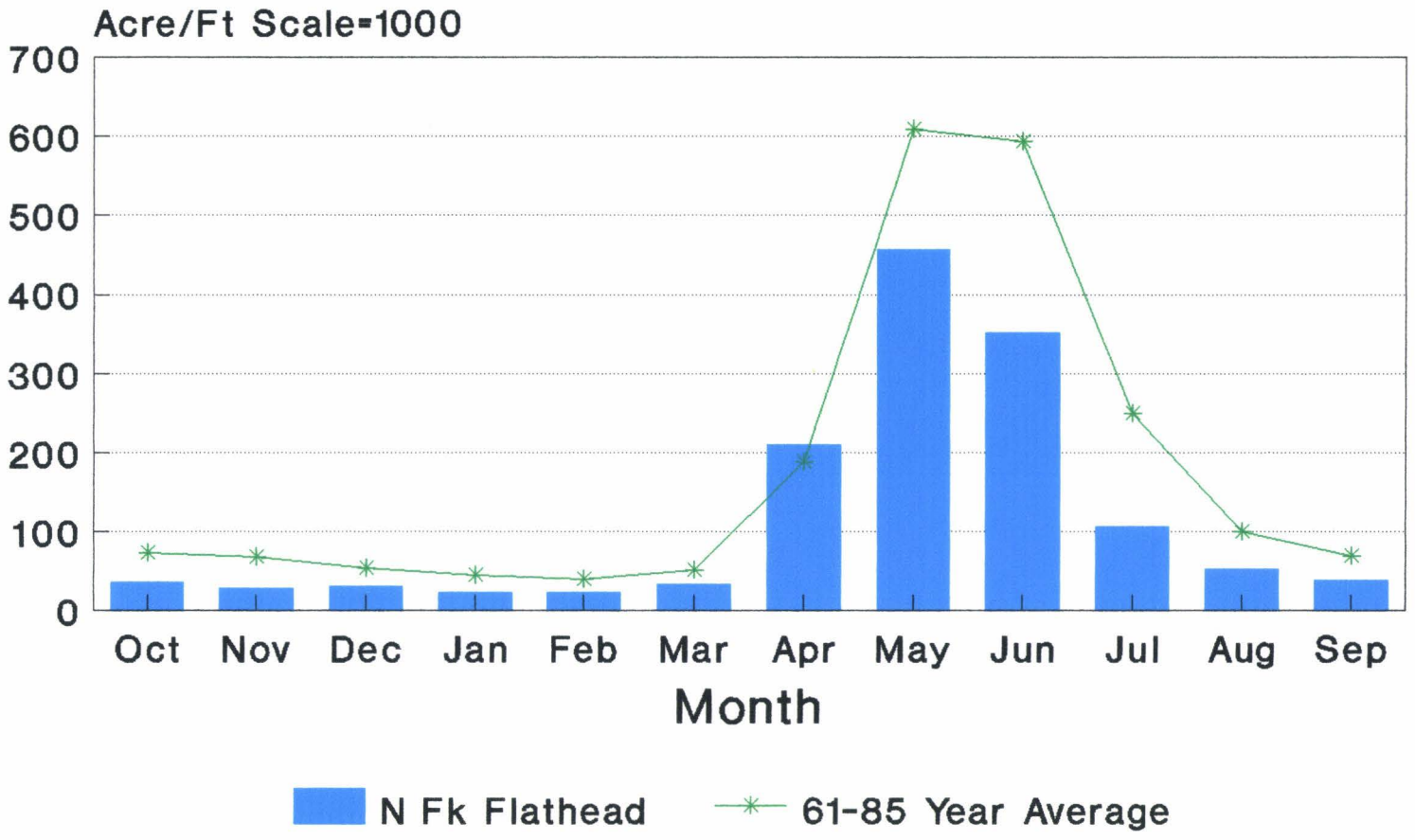
The city of Kalispell lies approximately 40 miles south of the Red Bench Fire. The NWS reporting station is located at the airport on the south side of the community across the highway from the Flathead National Forest supervisor's Office. The station is located at 2,965 ft msl which was approximately 2,880 ft below the elevation of the Red Bench Fire origin. Coordinates for the station location are latitude 48.18, longitude 114 16' (T28N, R21W, section 19). This station is used to help describe the climatology of the area for the Red Bench Fire because it has one of the longest weather records in the general vicinity even though it is not close to the fire origin in distance or elevation. Climatological comparisons can be made with the closer weather stations.

Precipitation

A review of the weather records from this station from between 1900-1988 provides a record of 86 years (1918, 1934, and 1949 are incomplete) which determines an average Water Year precipitation of 15.36 inches (Table A-22). Extreme precipitation years occurred in 1973 with 8.98 inches and in 1948 with 22.18 inches. The 1988 season closed with 13.24 inches and was the 63rd driest year in the 86 year record. A return interval was calculated of between 2 and 5 years for the 1988 Water Year at this station. Since the turn of the century this station has shown a slight increasing trend in Water Year precipitation of +1.8 inches, matching the increase noted at Park Headquarters in West Glacier. During the recent 25 year period of 1961-1985 precipitation was +0.7 inches

Figure A-6. Comparison of the 1988 Water Year (October - september) stream flow from the North Fork of the Flathead River near Columbia Falls with the historical monthly average.

1988 Stream Flow
Comparison with Average



Red Bench Fire (1988)

above the historical average. Extending the recent trend out to 28 years and covering 1961-1988 there is still a +0.7 inches above the historical average, with only the 1988 Water Year below the average. Most of the precipitation record for this site shows the Water Year totals to be average to slightly above average in moisture. Only the period 1910-1941 (except for isolated seasons) was extensively below average to average in moisture (27 seasons below normal, 4 seasons average to above average). The driest portion of this period extended from 1919 to 1932. Since 1941 most below average Water Years have been isolated occurrences, including 1988.

Prefire season precipitation in Kalispell averages 9.79 inches (87 seasons, 1900-1988) with extreme ranges of 5.55 inches during the 1924 season to 14.21 inches measured in 1960 (Table A-23). The 1988 prefire season at this location received 8.49 inches of moisture and was the 62nd driest prefire season on the record (Table A-24). Calculated return interval for the 1988 prefire season precipitation total was between 2 and 5 years. The first month of the 1988 prefire season not to have a monthly moisture deficit from average was May which recorded +1.07 inches above average (NOAA 1988; NOAA 1989). There has a been a positive trend of increasing moisture at the Kalispell station over it's record during prefire season months of about +0.9 inches. Most of this trend occurs after 1941 when more prefire seasons have received greater than normal moisture. The post 1941 "very moist" seasons also tended to receive much greater amounts of precipitation than did the earlier seasons. Since 1980 there has been a declining trend of prefire season moisture culminating in the 1988 season.

Precipitation during the summer fire season (June-August) at Kalispell averages 4.34 inches (88 seasons, 1900-1988) with extremes of 1.40 inches in 1929 to 8.31 inches in 1947 (Table A-25). During the 1988 fire season this station measured 2.65 inches of precipitation, ranking the 1988 season as the 73rd driest on record with a calculated return interval of between 5 and 10 years (Table A-26). 56.2% of the moisture during this season fell during June, the remained during July and August. Every month during the 1988 fire season at this station was accumulating a moisture deficit (NOAA 1988; NOAA 1989). There has been a trend of increasing moisture of +0.9 inches over the record of the 88 fire seasons. A greater percentage of the seasons after 1946 have received above normal precipitation, and greater amounts, than preceding that year. The 1988 fire season does not stand out as an exception from the record at this station.

An average of 5.58 inches has been measured at this station over 88 extended fire seasons (June-September) with extreme ranging from 1.91 inches in 1929 to 9.30 inches received in 1947 (Table A-27). 1988 extended fire season received 4.75 inches of moisture and was ranked as the 59th driest season with a calculated return interval of between 2 and 5 years (Table A-28). The month of September exceeded June in moisture received and had 44.2% of the total extended fire season precipitation. September turned out to be the second, and last month of the 1988 Water Year to have moisture in excess of the average with +0.99 inches (NOAA 1988; NOAA 1989).

Temperature

There is a 50% probability that the last killing frost of the spring will occur in Kalispell later than May 1st (Table A-29). By May 20th there is only a 10% probability of experiencing a temperature as cool. The first killing frost of the fall season has a 10% probability of occurring earlier than September 9th, and a 50% probability of occurring earlier than October 1st.

This station has an average annual temperature of 43.0F (based on 1900-1988 records), and an annual maximum average temperature of 53.9F. Kalispell has the warmest annual average temperature for any station examined in the geographic area of interest. July experiences the greatest average daily maximum temperature of 80.7F, followed closely by August with 78.9F. September average daily maximum temperature is considerably cooler with 67.4F. During July there is a 20% probability that at least one day will have a temperature of 103F or greater, and during august the same probability for a temperature of 95F.

From January through October, every month except July had temperatures at Kalispell which exceed the normal for the month (NOAA 1988; NOAA 1989). February through April had departures from normal of +4.2F, +6.0F, +5.0F; showing the very early warm spring season experienced in 1988. May temperatures were only +0.2F above the average for that month, but June regained the warmth experienced earlier in the year with temperatures +4.2F above normal. July was the only month with below normal temperatures, and not by much, only -0.1F. A return to slightly greater departures from normal were measured in August and September, +0.7F and +0.4F respectively. The month of October saw a return to unseasonably warm temperatures with +6.0F departure from normal. The annual departure from normal at this station as measured by the NWS for 1988 was eventually measured as +2.6F.

Snow Water Equivalent

To the northwest of Kalispell approximately 31 miles on the Stillwater State Forest (Montana Department of State Lands) lies the Herrin Junction SNOWTEL measuring station (latitude 48 42', longitude 114 37'; T34N, R23W, section 19). This mid to high elevation station, 4,850 ft msl, is measured February through June. This station normally has the highest snow water equivalent throughout the winter of all the stations in this region examined. During 1988 the snow water equivalent was considerably below the historical average of 11-12 years of record keeping (1977-1988)(Table A-30). Only the month of April approached the historical average measurement. April is normally the period of greatest snow water equivalent. May measurements had declined by 25.9%, normal decline is 15.6%. By June 1st the snow was gone. The lack of snow at this location by the beginning of June is not unusual.

Hungry Horse Dam, Montana

Hungry Horse Dam is located on the South Fork of the Flathead River approximately 39 miles southeast of the Polebridge Ranger Station (latitude 48 21', longitude 114 16'; T28N, R21W, section 22). This station is at 3,160 ft msl elevation, about 2,685 ft below the Red Bench Fire origin. The station is a NWS reporting site.

Precipitation

The Water Year has a 41 year period of record keeping (1948-1988), the shortest period of any stations examined. Average Water Year moisture received during that period is 33.08 inches with extremes of 21.97 inches in 1953 and 48.93 inches in 1974 (Table A-31). This station is the most moist recording site examined in the geographic area of interest. The 1988 Water Year received 29.08 inches of moisture and was ranked as the 32nd driest year with a return interval of between 2 and 5 years. During the 41 years of precipitation

records there has been a trend of increasing moisture of +4.6 inches. This trend is in part due to a period of mostly average to below average precipitation during the early record keeping, 1948-1958. During this ten year dry period only two seasons exceeded the average moisture for a Water Year. Since that time there has been a fairly even distribution of years on either side of the mythical "average year" marker, with moist years receiving much greater than average amounts. During the 25 year period between 1961-1985 the trend is not as great when the previous dry period is excluded, only +1.49 inches. Extending the recent record out to include 1988, the 28 year trend is +1.02 inches reflecting the effect of below average Water Year moisture received in 1987-1988.

Prefire season precipitation averages 22.35 inches with extreme ranges of 14.38 inches in 1977 and 40.63 inches in 1974 (Table A-32). The 1988 prefire season received 19.51 inches and was ranked the 33rd driest season in the 41 year record (Table A-33). The calculated return interval for a prefire season receiving moisture similar to 1988 is between 2 and 5 years. There has been only a slight trend of increasing moisture over the stations record of prefire seasons, +0.2 inches with periods of average to below average moisture at the beginning and end of the records off set by generally above normal moisture from 1959-1976. January was the first month of the Water Year at this station to receive a precipitation above normal, +0.05 inches. March, April, and May all received higher than normal monthly precipitation totals; +0.53 inches, +0.53 inches, and +1.53 inches (NOAA 1988; NOAA 1989).

Fire season records indicate an average precipitation of 6.99 inches with extremes of 3.28 inches in 1962 and 11.42 inches in 1954 (Table A-34). 1988 fire season received 4.69 inches at this station and ranked the 31st driest season of 41 seasons of record (Table A-35). The calculated return interval of the 1988 season is between 5 and 10 years. Over the fire season record there has been an increasing moisture trend of +1.1 inches. All three months of the 1988 fire season received below normal moisture with August experiencing the greatest departure from average, -1.31 inches (NOAA 1988; NOAA 1989).

During the extended fire season the average moisture received is 9.73 inches with extremes of 4.19 inches in 1979 and 15.36 inches in 1968 (Table A-36). The 1988 extended fire season received just below the average amount with 9.57 inches. That season was ranked 25th out of the 41 year record with a return interval of between 2 and 5 years (Table A-37). After three months of below average moisture during the regular fire season, September was above normal with a +2.32 inches departure from average (NOAA 1988; NOAA 1989).

Temperature

The last killing frost of the spring has a 50% probability of arriving later than April 25th and a 10% probability of beginning later than May 14th (Table A-38). The first killing frost of fall has a 10% probability of arriving before September 16th and a 50% probability of before October 8th. The average annual temperature for the site is 42.8F with an annual average daily maximum temperature of 53.2F (1948-1988 record). July experiences the greatest monthly average daily maximum of 80.0F, closely followed by August with 78.9F. During July there is a 20% probability that at least one day will have a temperature of 96F or greater, and during August of 95F or greater.

The 1988 Water Year started with October being cooler than normal with a departure from average of -1.2F. This initial pattern was reversed in November with unseasonably warm temperatures caused a +3.9F departure from average. December was only slightly below normal, -0.7F, and was then followed by a

rapidly warming late winter and spring peaking in June with a departure from average of +6.4F. The rest of the Water Year through September also averaged above normal temperatures, ranging from +1.8F in September to +3.7F in august (NOAA 1988; NOAA 1989).

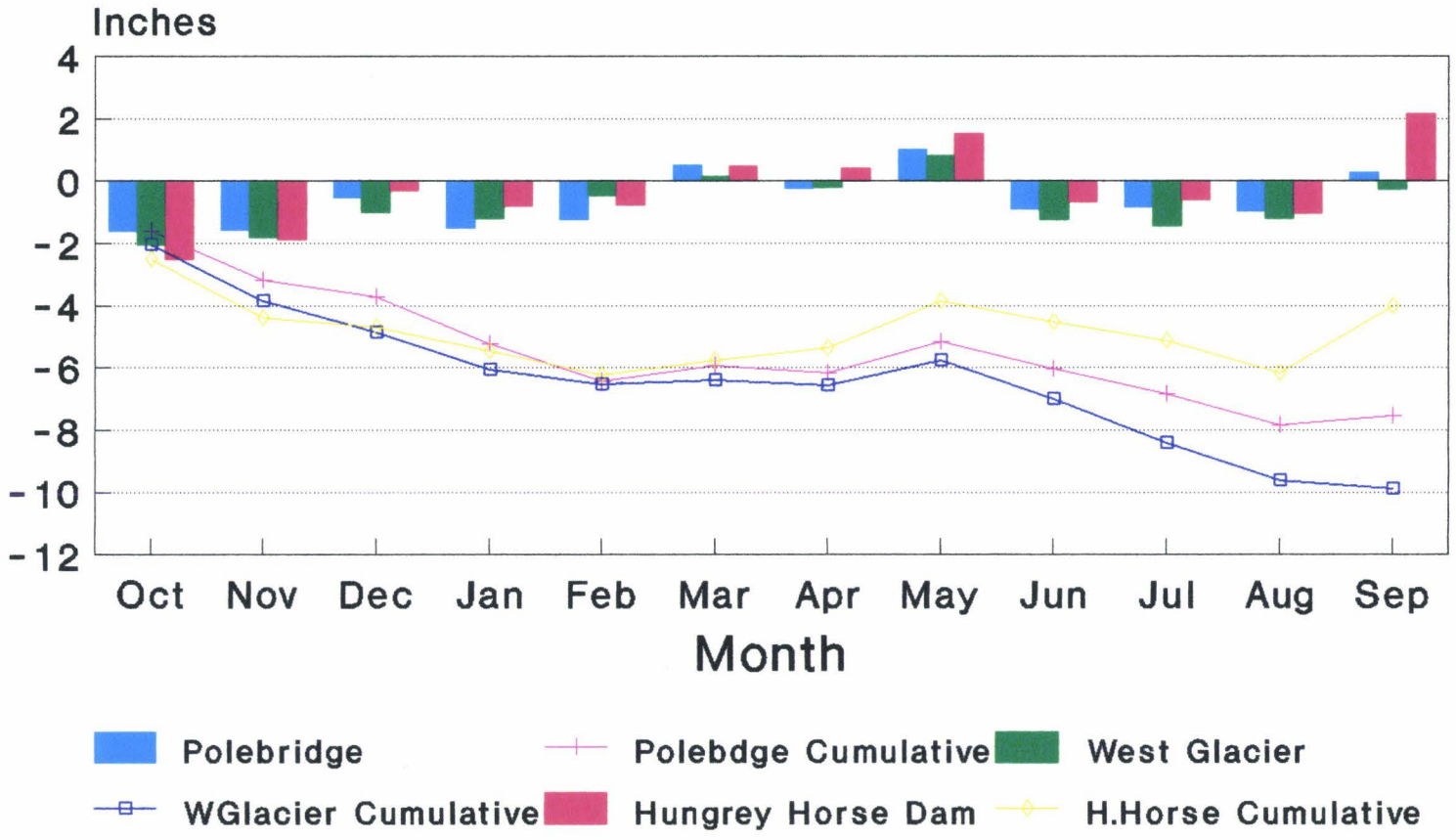
Climatic Characteristics of Severe Fire Seasons and the 1988 Season

Finklin (1985) evaluated the climatic characteristics of severe fire seasons in the Northern Rockies between 1910 and 1984 and classified three types of seasons; Main, Early, and Late. The Main Type has its peak warm, dry conditions relative to normal around late July. Early Type seasons start with dry, warm May-June weather with precipitation approximately 50% below the normal. This season tends to end quickly with a change to above normal precipitation, which may then be followed by a return to dry weather and renewed fire activity. In the Flathead National Forest area this early severe fire season peaks in late June or early July followed by rain. Severe fire seasons classified as Late Types frequently will have May-June precipitation averages about 100% of normal with maximum temperatures being normal or slightly below. Warmer, drier conditions tend to peak in late August or early September. This type of season was found to be only marginally "severe" and of relatively short duration. After all three types of seasons there is usually a return to cooler and wetter than normal conditions by late September. Of the 17 severe seasons in the Flathead National Forest area between 1910 and 1984 29.4% were classified as Early Types, 47.0% as Main, and 23.5% as Late Type severe fire seasons.

The 1988 season at the Polebridge Ranger Station fits most closely with Finklin's classification of the Late Type severe fire season. The May-June precipitation at this station was relatively moist and only +2.6% above normal. All of the moisture to move this time period above normal was received in May, June was below average in precipitation. However, the combined months moisture level is pretty close to the normal moisture pattern typically found in the Late Type season. July and August were much drier than normal with only 38.3% of average moisture in July and 28.6% in August. This fits the Late Type fire season with dry conditions peaking in late August - early September. May temperatures were slightly below normal at the station (-0.4F), while June temperatures were unseasonably warm (+3.0F) but not extreme, again a fairly close fit to the Late Type season description. July-August temperatures at the Polebridge Ranger Station were cooler than normal for this normally warmest time of the year, with departures from average of -1.4F in July and -0.5F in August. However, the near normal temperatures and the dry July-early September period combined to produce a marginally severe Late Type season of short duration. Without the strong wind event occurring in association with the dry-cold frontal passage and driving fires all ready in existence, the 1988 fire season in this area could have very easily escaped historical notice. The return to wetter than normal conditions, as predicted by Finklin (1985), by late September did develop at all stations. The 1988 fire season in this location was probably only marginally impacted by the effect of cumulative drought conditions (Figure A-7). While moisture levels had been below average since 1982, the winter and spring preceding the 1988 fire season were sufficient to bring fuel moistures back to saturation levels. The warm temperatures in March and April would have been conducive to increased early season snow melt and exposure of large fuel particles for drying, but moisture received during the spring months was sufficient to prevent any rapid drying. Significant drying would have to wait until July and August when normal high

Figure A-7. 1988 Water Year (October - September) difference from average monthly precipitation totals, and cumulative deficit for the Polebridge Ranger Station (Glacier National Park), Glacier National Park Headquarters (West Glacier), and Hungry Horse Dam.

1988 Water Year Precipitation
Difference from Average



Red Bench Fire (1988)

temperatures and gradually drying conditions would combine to create an environment favorable for fire spread peaking in early September. The fire season then declined rapidly in severity but burning conditions would extend well into October.

Typically, Finklin (1985) found that during severe seasons there is at least one 30 day period between June 1st and September that will have less than 25% of the average precipitation for the period. The Polebridge Ranger Station came closest to achieving this low moisture level with the month of August when only 28.6% of average was received. The reporting stations located at Park Headquarters in West Glacier and at the airport in Kalispell were both closer to this feature found during severe seasons. Park Headquarters in August was 23.0% of average, while during the same month Kalispell was 25.8%. Hungry Horse Dam stayed relatively moist with 46.3% of average during August. However, there is a strong gradient of increasing moisture extending "down valley" from Polebridge toward West Glacier and Hungry Horse were their lower percentages may be similar to actual moisture levels received at Polebridge. Another feature of severe seasons found by Finklin (1985) was the 30 day maximum temperatures will average 5F to 6F above normal. Never during the June through September period did the Polebridge Ranger Station achieve temperatures that warm, June was closest with +3.0F. West Glacier and Kalsipell did not achieve that feature of a severe season either, only reaching +4.8F and +4.2F in June and all other months well below the 5F-6F positive departure from average. Hungry Horse Dam did exceed this temperature feature in June with a departure of +6.4F and was also the most consistent station to maintain greater than normal temperatures during the 1988 extended fire season.

Although Finkin (1985) did not examine the effect of dry, mild winter and early spring weather on the development of severe fire seasons, he does mention that early snowmelt and the drying of forested areas at his time of the year could be an important factor. Snow water equivalent measured at stations in or near the mountains surrounding the North Fork of the Flathead River valley were mostly below average throughout the 1988 winter months. Measurements taken in mid May showed moisture levels much below normal. In June when three of the four stations are known to historically still have snow, there was none left in 1988. Warm late winter and spring temperatures removed what snow had accumulated earlier than normal, exposing forest fuel to the potential for an extended drying season. Snow depth and moisture content, while being important, are not the principal factors affected the moisture content of large fuel particles. McCammon (1976) clearly found that it takes 150 days under continual snow cover for 1000 Hour fuel to attain maximum fiber saturation of approximately 39%. He also concluded that the duration of snowmelt is the major factor in liquid moisture absorption. Large fuel particles in the Polebridge Ranger station area were already very dry following a warm, dry summer and fall in 1987. Assuming a snow cover from December 1st through May 15th at mid-elevations (the Emery Creek and Herrin Junction Soil Conservation Service SNOWTEL sites are at elevations of 4,350 and 4,850 ft msl respectively, and were bare before June 1st) provides a snow cover for 166 days. Most likely most mid to high elevations had a snow cover prior to December 1st. Polebridge experienced an average temperature in November 1987 of 31.3F, all of the other low elevation recording stations were warmer and were probably still bare going into December. The warm temperatures of February through June in the vicinities of West Glacier, Hungry Horse, and Kalispell; and of March and April at Polebridge certainly hastened the duration of snowmelt in the spring. This would have allowed for an earlier than normal start to the large fuel particle drying process had spring rains not kept those moisture levels elevated.

July was determined by Finklin (1985) to be the critical month in development of a severe fire season in the Northern Rocky Mountains. He found that 75% of the severe seasons examined in the Northern Region of the Forest Service had warm, dry Julys in respect to precipitation and average maximum temperatures. Only one season had a wetter and cooler than normal July. He also determined that few severe seasons had moist, cool Junes. Except at Hungry Horse Dam, July temperature measurements were slightly cooler than normal along the edge of the Flathead National Forest and Glacier National Park in 1988. Even August at Polebridge was slightly cooler than normal that year. June through August, 1988, at these locations were all drier than normal months.

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Table A-1. Historical Water Year precipitation at the Polebridge Ranger Station, Polebridge, MT.

Station : 6615, POLE BRIDGE
Unit = inches

yr	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep	SUM
46			2.00	2.14	1.49	1.44	0.63	1.50	2.19	1.03	1.11	1.28	*****
47	2.92	5.31	2.06	2.08	1.39	1.73	0.36	0.90	2.97	0.32	2.99	0.67	23.70
48	3.70	0.85	1.22	1.54	2.69	1.74	2.24	1.88	3.44	3.74	1.16	0.09	24.29
49	0.52	2.58	2.06	1.07	4.38	1.25	1.08	2.18	1.37	2.74	0.63	1.01	20.87
50	1.32	2.96	3.06	4.28	1.74	2.73	0.88	0.70	1.61	1.02	0.96	0.70	21.96
51	3.51	2.07	2.34	3.48	3.19	2.05	1.26	2.45	2.55	1.38	3.14	2.91	30.33
52	4.34	1.77	4.69	2.19	0.99	0.59	0.48	1.40	3.35	0.90	0.72	0.39	21.81
53	0.07	0.49	1.50	6.32	1.86	0.86	2.47	1.70	3.10	0.08	1.14	0.96	20.55
54	0.43	2.32	4.13	6.92	3.04	2.93	3.39	0.97	1.65	1.96	4.81	0.91	33.46
55	1.16	1.55	0.96	0.67	1.94	1.95	1.01	1.36	1.68	2.14	0.01	1.37	15.80
56	2.77	2.86	4.47	1.99	1.51	1.82	1.81	1.40	2.45	1.60	1.09	1.34	25.11
57	1.44	0.64	2.99	1.54	3.27	0.71	1.52	1.89	3.44	1.58	0.54	0.43	19.99
58	3.31	0.53	2.75	1.99	2.64	1.09	2.57	1.18	3.59	0.74	1.09	2.06	23.54
59	1.68	4.21	2.49	5.54	1.97	0.52	2.71	3.38	1.40	0.11	1.21	4.45	29.67
60	3.22	4.79	1.57	1.44	1.25	1.59	1.12	2.47	0.61	0.10	1.86	0.56	20.58
61	1.12	4.08	1.17	1.69	3.57	0.77	2.07	3.46	0.54	1.69	0.64	2.44	23.24
62	2.37	1.54	3.88	1.38	1.27	1.71	1.43	1.77	0.71	1.59	1.16	0.90	20.21
63	2.21	3.12	2.49	1.65	1.98	1.72	0.90	0.94	4.35	0.81	1.57	1.58	23.32
64	1.28	2.48	1.77	2.74	0.72	2.52	0.94	3.14	3.21	1.09	1.35	1.87	23.11
65	1.44	2.54	5.31	2.90	2.47	0.64	2.42	1.11	2.41	0.91	1.71	2.51	26.37
66	0.50	2.34	2.19	3.35	0.80	1.79	1.26	1.35	5.50	1.45	0.90	0.75	22.13
67	2.04	4.12	2.18	3.92	1.61	2.10	0.51	0.87	0.86	0.00	0.00	0.09	18.30
68	3.97	1.48	2.77	1.68	1.68	0.88	0.84	2.94	1.84	0.77	2.82	2.95	24.62
69	2.15	1.61	3.07	5.38	0.69	0.75	1.17	1.18	3.67	0.31	0.00	1.22	21.20
70	1.19	0.47	1.75	3.94	1.63	1.40	0.54	2.23	2.56	0.95	0.28	2.33	19.27
71	0.99	4.01	5.14	6.79	2.28	2.85	0.80	2.75	5.28	2.17	1.55	0.48	35.09
72	2.07	2.36	4.54	5.36	3.31	1.81	1.72	1.41	1.65	1.66	1.08	1.70	28.67
73	1.65	0.46	3.76	1.91	1.31	1.31	1.16	0.94	1.54	0.37	1.00	1.19	16.60
74	1.37	6.08	3.34	5.80	2.79	2.51	1.89	1.22	1.21	1.13	1.05	1.07	29.46
75	0.10	3.15	2.34	3.10	3.36	1.39	0.83	1.79	1.96	1.80	2.79	0.51	23.12
76	3.99	1.59	2.98	2.21	3.29	0.94	0.91	1.98	2.40	2.18	2.99	0.70	26.16
77	0.68	1.29	0.71	1.04	0.66	1.64	0.46	1.87	0.79	1.57	2.25	1.66	14.62
78	0.70	2.16	3.56	1.38	0.82	0.49	1.29	3.30	1.29	3.42	2.64	1.28	22.33
79	0.46	1.80	1.73	1.21	3.53	1.45	1.95	1.53	1.32	0.60	1.26	0.29	17.13
80	1.91	0.18	2.17	3.46	1.64	1.41	0.72	3.83	3.71	1.31	1.24	1.24	22.82
81	0.34	2.94	5.69	0.87	1.67	0.76	1.77	3.04	3.88	1.35	0.66	0.77	23.74
82	0.61	2.03	2.73	4.00	3.81	2.43	2.26	0.42	4.12	1.40	0.66	1.49	25.96
83	0.98	2.41	3.20	2.38	1.14	1.87	1.12	0.29	2.98	3.05	1.06	1.15	21.63
84	0.56	2.74	1.72	1.48	0.51	1.03	1.15	2.73	1.61	0.67	1.32	2.61	18.13
85	2.38	2.74	2.35	0.05	1.62	0.82	1.04	1.01	2.06	0.41	1.44	2.58	18.50
86	2.53	2.36	0.48	2.17	2.36	1.09	0.79	2.26	1.83	1.22	0.53	1.84	19.51
87	0.69	3.57	0.37	1.11	1.62	2.81	0.93	0.61	1.26	3.23	1.82	0.17	18.19
88	0.09	0.80	2.11	1.24	0.79	2.05	1.10	2.83	1.46	0.51	0.39	1.63	15.00
all years													
ave	1.70	2.37	2.65	2.73	2.01	1.53	1.34	1.82	2.36	1.33	1.36	1.35	22.62
yrs	(42)	(42)	(43)	(43)	(43)	(43)	(43)	(43)	(43)	(43)	(43)	(43)	(42)
1961-1985 average :													
	1.50	2.39	2.90	2.79	1.93	1.48	1.25	1.88	2.46	1.31	1.34	1.41	22.63
yrs	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)

Table A-2. Prefire season (October - May) precipitation at the Polebridge Ranger Station, Polebridge, MT.

Weight: 1.00 Station: 6615, POLE BRIDGE

Start Yr. 46 End Yr. 88
Weights for months:
October - 1.00
November - 1.00
December - 1.00
January - 1.00
February - 1.00
March - 1.00
April - 1.00
May - 1.00

Year (Wt.)	INDEX TOTAL
46	*****
47	16.75
48	15.86
49	15.12
50	17.67
51	20.35
52	16.45
53	15.27
54	24.13
55	10.60
56	18.63
57	14.00
58	16.00
59	22.50
60	17.45
61	17.93
62	15.35
63	15.01
64	15.59
65	18.83
66	13.58
67	17.35
68	16.24
69	16.00
70	13.15
71	25.61
72	22.58
73	12.50
74	25.00
75	16.06
76	17.89
77	8.35
78	13.70
79	13.66
80	15.32
81	17.08
82	18.29
83	13.39
84	11.92
85	12.01
86	14.09
87	11.71
88	11.01
AVERAGE	16.2
MAXIMUM	25.6
MINIMUM	8.4

****

number of values = 42
arithmetic average = 16.20 log average = 1.198
std. deviation = 3.81 log std. dev. = 0.102
coeff of variation = 0.24 log coef. var. = 0.085
arithmetic skew = 0.060 log skew = -0.110

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	7.33	9.15	8.98
95.00	1.053	9.93	10.73	10.66
90.00	1.111	11.31	11.68	11.66
80.00	1.250	12.99	12.95	12.97
50.00	2.000	16.20	15.78	15.85
20.00	5.000	19.41	19.22	19.24
10.00	10.000	21.09	21.30	21.24
5.00	20.000	22.48	23.20	23.02
1.00	100.000	25.07	27.21	26.70

Table A-3. Pre fire season (October - May) historical precipitation at the Polebridge Ranger Station, Polebridge, MT ranked in declining amount.

Gage No. Station : 6615,POLE BRIDGE

for the months October - May

Ranks #	Water Year	Value inches	Weibull plot pos.	Value log10
1	71	25.61	0.047	1.408
2	74	25.00	0.070	1.398
3	54	24.13	0.093	1.383
4	72	22.58	0.116	1.354
5	59	22.50	0.140	1.352
6	51	20.35	0.163	1.309
7	65	18.83	0.186	1.275
8	56	18.63	0.209	1.270
9	82	18.29	0.233	1.262
10	61	17.93	0.256	1.254
11	76	17.89	0.279	1.253
12	50	17.67	0.302	1.247
13	60	17.45	0.326	1.242
14	67	17.35	0.349	1.239
15	81	17.08	0.372	1.232
16	47	16.75	0.395	1.224
17	52	16.45	0.419	1.216
18	68	16.24	0.442	1.211
19	75	16.06	0.465	1.206
20	58	16.06	0.488	1.206
21	69	16.00	0.512	1.204
22	48	15.86	0.535	1.200
23	62	15.85	0.558	1.200
24	64	15.59	0.581	1.193
25	80	15.32	0.605	1.185
26	53	15.27	0.628	1.184
27	49	15.12	0.651	1.180
28	63	15.01	0.674	1.176
29	86	14.09	0.698	1.149
30	57	14.00	0.721	1.146
31	78	13.70	0.744	1.137
32	79	13.66	0.767	1.135
33	66	13.58	0.791	1.133
34	83	13.39	0.814	1.127
35	70	13.15	0.837	1.119
36	73	12.50	0.860	1.097
37	85	12.01	0.884	1.080
38	84	11.92	0.907	1.076
39	87	11.71	0.930	1.069
40	88	11.01	0.953	1.042
41	55	10.60	0.977	1.025
42	77	8.35	1.000	0.922

number of values = 42
arithmetic average = 16.20log average = 1.198

std. deviation = 3.81log std. dev. = 0.102
coeff of variation = 0.24log cof. var. = 0.085
arithmetic skew = 0.66Olog skew = -0.110

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	7.33	9.15	8.98
95.00	1.053	9.93	10.73	10.66
90.00	1.111	11.31	11.68	11.66
80.00	1.250	12.99	12.95	12.97
50.00	2.000	16.20	15.78	15.85
20.00	5.000	19.41	19.22	19.24
10.00	10.000	21.09	21.30	21.24
5.00	20.000	22.48	23.20	23.02
1.00	100.000	25.07	27.21	26.70

Table A-4. Fire Season (June - August) historical precipitation at the Polebridge Ranger Station, Polebridge, MT.

weight: 1.00 Station: 6615, POLE BRIDGE

Start Yr. 46 End Yr. 88

Year (Wt.)	June (1.00)	July (1.00)	August (1.00)	INDEX TOTAL
46	2.19	1.03	1.11	4.33
47	2.97	0.32	2.99	6.28
48	3.44	3.74	1.16	8.34
49	1.37	2.74	0.63	4.74
50	1.61	1.02	0.96	3.59
51	2.55	1.38	3.14	7.07
52	3.35	0.90	0.72	4.97
53	3.10	0.08	1.14	4.32
54	1.65	1.96	4.81	8.42
55	1.68	2.14	0.01	3.83
56	2.45	1.60	1.09	5.14
57	3.44	1.58	0.54	5.56
58	3.59	0.74	1.09	5.42
59	1.40	0.11	1.21	2.72
60	0.61	0.10	1.86	2.57
61	0.54	1.69	0.64	2.87
62	0.71	1.59	1.16	3.46
63	4.35	0.81	1.57	6.73
64	3.21	1.09	1.35	5.65
65	2.41	0.91	1.71	5.03
66	5.50	1.45	0.90	7.85
67	0.86	0.00	0.00	0.86
68	1.84	0.77	2.82	5.43
69	3.67	0.31	0.00	3.98
70	2.56	0.95	0.28	3.79
71	5.28	2.17	1.55	9.00
72	1.65	1.66	1.08	4.39
73	1.54	0.37	1.00	2.91
74	1.21	1.13	1.05	3.39
75	1.96	1.80	2.79	6.55
76	2.40	2.18	2.99	7.57
77	0.79	1.57	2.25	4.61
78	1.29	3.42	2.64	7.35
79	1.32	0.60	1.26	3.18
80	3.71	1.31	1.24	6.26
81	3.88	1.35	0.66	5.89
82	4.12	1.40	0.66	6.18
83	2.98	3.05	1.06	7.09
84	1.61	0.67	1.32	3.60
85	2.06	0.41	1.44	3.91
86	1.83	1.22	0.53	3.58
87	1.26	3.23	1.82	6.31
88	1.46	0.51	0.39	2.36
			AVERAGE	5.05
			MAXIMUM	9.00
			MINIMUM	0.86

****

number of values = 43

arithmetic average = 5.05 log average = 0.668

std. deviation = 1.87 log std. dev. = 0.191

coeff of variation = 0.37 log cof. var. = 0.285

arithmetic skew = 0.177 log skew = -1.330

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	0.71	1.68	1.13
95.00	1.053	1.98	2.26	2.00
90.00	1.111	2.66	2.65	2.59
80.00	1.250	3.48	3.22	3.40
50.00	2.000	5.05	4.66	5.12
20.00	5.000	6.62	6.74	6.72
10.00	10.000	7.44	8.18	7.41
5.00	20.000	8.12	9.59	7.87
1.00	100.000	9.39	12.93	8.47

Table A-5. Fire season (June - August) historical precipitation at the Polebridge Ranger Station, Polebridge, MT ranked in declining amount.

Gage No. Station : 6615,POLE BRIDGE

Ranks #	WY #	Jun inches	Jul inches	Aug inches	Total inches	Weibull plotpos	Value log10
1	71	5.28	2.17	1.55	9.00	0.023	0.954
2	54	1.65	1.96	4.81	8.42	0.045	0.925
3	48	3.44	3.74	1.16	8.34	0.068	0.921
4	66	5.50	1.45	0.90	7.85	0.091	0.895
5	76	2.40	2.18	2.99	7.57	0.114	0.879
6	78	1.29	3.42	2.64	7.35	0.136	0.866
7	83	2.98	3.05	1.06	7.09	0.159	0.851
8	51	2.55	1.38	3.14	7.07	0.182	0.849
9	63	4.35	0.81	1.57	6.73	0.205	0.828
10	75	1.96	1.80	2.79	6.55	0.227	0.816
11	87	1.26	3.23	1.82	6.31	0.250	0.800
12	47	2.97	0.32	2.99	6.28	0.273	0.798
13	80	3.71	1.31	1.24	6.26	0.295	0.797
14	82	4.12	1.40	0.66	6.18	0.318	0.791
15	81	3.88	1.35	0.66	5.89	0.341	0.770
16	64	3.21	1.09	1.35	5.65	0.364	0.752
17	57	3.44	1.58	0.54	5.56	0.386	0.745
18	68	1.84	0.77	2.82	5.43	0.409	0.735
19	58	3.59	0.74	1.09	5.42	0.432	0.734
20	56	2.45	1.60	1.09	5.14	0.455	0.711
21	65	2.41	0.91	1.71	5.03	0.477	0.702
22	52	3.35	0.90	0.72	4.97	0.500	0.696
23	49	1.37	2.74	0.63	4.74	0.523	0.676
24	77	0.79	1.57	2.25	4.61	0.545	0.664
25	72	1.65	1.66	1.08	4.39	0.568	0.642
26	46	2.19	1.03	1.11	4.33	0.591	0.636
27	53	3.10	0.08	1.14	4.32	0.614	0.635
28	69	3.67	0.31	0.00	3.98	0.636	0.600
29	85	2.06	0.41	1.44	3.91	0.659	0.592
30	55	1.68	2.14	0.01	3.83	0.682	0.583
31	70	2.56	0.95	0.28	3.79	0.705	0.579
32	84	1.61	0.67	1.32	3.60	0.727	0.556
33	50	1.61	1.02	0.96	3.59	0.750	0.555
34	86	1.83	1.22	0.53	3.58	0.773	0.554
35	62	0.71	1.59	1.16	3.46	0.795	0.539
36	74	1.21	1.13	1.05	3.39	0.818	0.530
37	79	1.32	0.60	1.26	3.18	0.841	0.502
38	73	1.54	0.37	1.00	2.91	0.864	0.464
39	61	0.54	1.69	0.64	2.87	0.886	0.458
40	59	1.40	0.11	1.21	2.72	0.909	0.435
41	60	0.61	0.10	1.86	2.57	0.932	0.410
42	88	1.46	0.51	0.39	2.36	0.955	0.373
43	67	0.86	0.00	0.00	0.86	0.977	-0.066

number of values = 43
arithmetic average = 5.05log average = 0.668

std. deviation = 1.87log std. dev. = 0.191
coeff of variation = 0.37log cof. var. = 0.285
arithmetic skew = 0.17log skew = -1.330

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	0.71	1.68	1.13
95.00	1.053	1.98	2.26	2.00
90.00	1.111	2.66	2.65	2.59
80.00	1.250	3.48	3.22	3.40
50.00	2.000	5.05	4.66	5.12
20.00	5.000	6.62	6.74	6.72
10.00	10.000	7.44	8.18	7.41
5.00	20.000	8.12	9.59	7.87
1.00	100.000	9.39	12.93	8.47

Table A-6. Extended fire season (June - September) historical precipitation at the Polebridge Ranger Station, Polebridge, MT.

Weight: 1.00 Station: 6615, POLE BRIDGE

Start Yr. 46 End Yr. 88

Year	June	July	August	September	INDEX
(Wt.)	(1.00)	(1.00)	(1.00)	(1.00)	TOTAL
46	2.19	1.03	1.11	1.28	5.61
47	2.97	0.32	2.99	0.67	6.95
48	3.44	3.74	1.16	0.09	8.43
49	1.37	2.74	0.63	1.01	5.75
50	1.61	1.02	0.96	0.70	4.29
51	2.55	1.38	3.14	2.91	9.98
52	3.35	0.90	0.72	0.39	5.36
53	3.10	0.08	1.14	0.96	5.28
54	1.65	1.96	4.81	0.91	9.33
55	1.68	2.14	0.01	1.37	5.20
56	2.45	1.60	1.09	1.34	6.48
57	3.44	1.58	0.54	0.43	5.99
58	3.59	0.74	1.09	2.06	7.48
59	1.40	0.11	1.21	4.45	7.17
60	0.61	0.10	1.86	0.56	3.13
61	0.54	1.69	0.64	2.44	5.31
62	0.71	1.59	1.16	0.90	4.36
63	4.35	0.81	1.57	1.58	8.31
64	3.21	1.09	1.35	1.87	7.52
65	2.41	0.91	1.71	2.51	7.54
66	5.50	1.45	0.90	0.75	8.60
67	0.86	0.00	0.00	0.09	0.95
68	1.84	0.77	2.82	2.95	8.38
69	3.67	0.31	0.00	1.22	5.20
70	2.56	0.95	0.28	2.33	6.12
71	5.28	2.17	1.55	0.48	9.48
72	1.65	1.66	1.08	1.70	6.09
73	1.54	0.37	1.00	1.19	4.10
74	1.21	1.13	1.05	1.07	4.46
75	1.96	1.80	2.79	0.51	7.06
76	2.40	2.18	2.99	0.70	8.27
77	0.79	1.57	2.25	1.66	6.27
78	1.29	3.42	2.64	1.28	8.63
79	1.32	0.60	1.26	0.29	3.47
80	3.71	1.31	1.24	1.24	7.50
81	3.88	1.35	0.66	0.77	6.66
82	4.12	1.40	0.66	1.49	7.67
83	2.98	3.05	1.06	1.15	8.24
84	1.61	0.67	1.32	2.61	6.21
85	2.06	0.41	1.44	2.58	6.49
86	1.83	1.22	0.53	1.84	5.42
87	1.26	3.23	1.82	0.17	6.48
88	1.46	0.51	0.39	1.63	3.99
			AVERAGE		6.40
			MAXIMUM		9.98
			MINIMUM		0.95

****

number of values = 43

arithmetic average = 6.40 log average = 0.780

std. deviation = 1.88 log std. dev. = 0.173

coeff of variation = 0.29 log coef. var. = 0.222

arithmetic skew = -0.437 log skew = -2.512

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	2.03	2.39	1.30
95.00	1.053	3.31	3.13	2.70
90.00	1.111	3.99	3.62	3.67
80.00	1.250	4.82	4.31	4.91
50.00	2.000	6.40	6.03	6.96
20.00	5.000	7.98	8.43	8.00
10.00	10.000	8.81	10.05	8.19
5.00	20.000	9.49	11.61	8.25
1.00	100.000	10.77	15.23	8.28

Table A-7. Extended fire season (june - September) precipitation at the Polebridge Ranger Station, Polebridge, MT ranked in declining amount.

Gage No. Station : 6615,POLE BRIDGE

Ranks #	WY #	Jun inches	Jul inches	Aug inches	Sep inches	Total inches	Weibull plotpos	Value log10
1	51	2.55	1.38	3.14	2.91	9.98	0.023	0.999
2	71	5.28	2.17	1.55	0.48	9.48	0.045	0.977
3	54	1.65	1.96	4.81	0.91	9.33	0.068	0.970
4	78	1.29	3.42	2.64	1.28	8.63	0.091	0.936
5	66	5.50	1.45	0.90	0.75	8.60	0.114	0.934
6	48	3.44	3.74	1.16	0.09	8.43	0.136	0.926
7	68	1.84	0.77	2.82	2.95	8.38	0.159	0.923
8	63	4.35	0.81	1.57	1.58	8.31	0.182	0.920
9	76	2.40	2.18	2.99	0.70	8.27	0.205	0.918
10	83	2.98	3.05	1.06	1.15	8.24	0.227	0.916
11	82	4.12	1.40	0.66	1.49	7.67	0.250	0.885
12	65	2.41	0.91	1.71	2.51	7.54	0.273	0.877
13	64	3.21	1.09	1.35	1.87	7.52	0.295	0.876
14	80	3.71	1.31	1.24	1.24	7.50	0.318	0.875
15	58	3.59	0.74	1.09	2.06	7.48	0.341	0.874
16	59	1.40	0.11	1.21	4.45	7.17	0.364	0.856
17	75	1.96	1.80	2.79	0.51	7.06	0.386	0.849
18	47	2.97	0.32	2.99	0.67	6.95	0.409	0.842
19	81	3.88	1.35	0.66	0.77	6.66	0.432	0.823
20	85	2.06	0.41	1.44	2.58	6.49	0.455	0.812
21	56	2.45	1.60	1.09	1.34	6.48	0.477	0.812
22	87	1.26	3.23	1.82	0.17	6.48	0.500	0.812
23	77	0.79	1.57	2.25	1.66	6.27	0.523	0.797
24	84	1.61	0.67	1.32	2.61	6.21	0.545	0.793
25	70	2.56	0.95	0.28	2.33	6.12	0.568	0.787
26	72	1.65	1.66	1.08	1.70	6.09	0.591	0.785
27	57	3.44	1.58	0.54	0.43	5.99	0.614	0.777
28	49	1.37	2.74	0.63	1.01	5.75	0.636	0.760
29	46	2.19	1.03	1.11	1.28	5.61	0.659	0.749
30	86	1.83	1.22	0.53	1.84	5.42	0.682	0.734
31	52	3.35	0.90	0.72	0.39	5.36	0.705	0.729
32	61	0.54	1.69	0.64	2.44	5.31	0.727	0.725
33	53	3.10	0.08	1.14	0.96	5.28	0.750	0.723
34	69	3.67	0.31	0.00	1.22	5.20	0.773	0.716
35	55	1.68	2.14	0.01	1.37	5.20	0.795	0.716
36	74	1.21	1.13	1.05	1.07	4.46	0.818	0.649
37	62	0.71	1.59	1.16	0.90	4.36	0.841	0.639
38	50	1.61	1.02	0.96	0.70	4.29	0.864	0.632
39	73	1.54	0.37	1.00	1.19	4.10	0.886	0.613
40	88	1.46	0.51	0.39	1.63	3.99	0.909	0.601
41	79	1.32	0.60	1.26	0.29	3.47	0.932	0.540
42	60	0.61	0.10	1.86	0.56	3.13	0.955	0.496
43	67	0.86	0.00	0.00	0.09	0.95	0.977	-0.022

number of values = 43
arithmetic average = 6.40log average = 0.780

std. deviation = 1.88log std. dev. = 0.173
coeff of variation = 0.29log cof. var. = 0.222
arithmetic skew = -0.437log skew = -2.512

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	2.03	2.39	1.30
95.00	1.053	3.31	3.13	2.70
90.00	1.111	3.99	3.62	3.67
80.00	1.250	4.82	4.31	4.91
50.00	2.000	6.40	6.03	6.96
20.00	5.000	7.98	8.43	8.00
10.00	10.000	8.81	10.05	8.19
5.00	20.000	9.49	11.61	8.25
1.00	100.000	10.77	15.23	8.28

Table A-8. Polebridge Ranger Station, Polebridge, MT climatological summary.

TAPS Station : POLE BRIDGE, 6615
start yr. - 1948 end yr. - 1988

Month	Temperature: avg daily max	avg daily min	avg	2 years in 10 will have: max temp. >than	min temp. <than	avg no. of grow'n degree days*	Precipitation: avg (in.)	2 yrs in 10 will have: less than (in.)	more than (in.)	average number of days with 0.10 inch or more
January	27.5	6.3	16.9	47	-38	0	2.84	1.18	4.26	9
February	35.9	11.8	23.8	53	-30	1	2.03	1.15	2.81	6
March	42.1	16.4	29.3	61	-21	5	1.52	0.90	2.08	5
April	52.8	25.0	38.9	87	5	60	1.34	0.79	1.83	4
May	63.5	32.1	47.8	83	16	242	1.82	1.00	2.55	5
June	70.9	38.3	54.6	89	25	425	2.34	1.26	3.29	6
July	79.5	40.5	60.0	94	28	576	1.36	0.54	2.11	4
August	78.9	39.1	59.0	95	27	569	1.35	0.77	2.07	4
September	67.9	32.2	50.1	89	17	289	1.36	0.53	2.06	4
October	54.7	25.3	40.0	78	7	80	1.66	0.61	2.53	5
November	37.8	18.5	28.2	58	-17	6	2.34	1.04	3.46	6
December	29.7	10.8	20.3	48	-30	0	2.72	1.51	3.79	8
Yearly :										
Average	53.4	24.7	39.1	----	----	----	---	---	---	---
Extreme	~~170~~ 103	-46	---	106	-41	----	---	---	---	---
Total	---	---	---	----	----	2253	22.70	14.97	27.39	66

*A growing degree day is a unit of heat available for plant growth. It can be calculated by adding the maximum and minumum daily temperatures, dividing the sum by 2, and subtracting the temperature below which growth is minimal for the principal crops in the area (Threshold : 40.0 deg. F)

FROST Station : POLE BRIDGE, 6615
start yr. - 1948 end yr. - 1988

Probability	Temperature: 24F or lower	28F or lower	32F or lower
Last freezing temperature in spring : March-June			
1 year in 10 later than--	June 7	June 27	July 3
2 year in 10 later than--	May 31	June 21	June 29
5 year in 10 later than--	May 18	June 8	June 22
First freezing temperature in fall : August-Nov.			
1 yr in 10 earlier than--	September 7	August 17	July 31
2 yr in 10 earlier than--	September 11	August 22	August 4
5 yr in 10 earlier than--	September 19	August 31	August 12

Table A-9. Historical monthly snow depth and snow water equivalent measurements from Kishenehn, Glacier National Park.

Station : 14AC6, KISHENEHN

Unit = inches

year/	January			February			March			April			May			June		
card	date	dep	swe	date	dep	swe	date	dep	swe	date	dep	swe	date	dep	swe	date	dep	swe
46-1							3/06	045	10.7	4/02	030	8.5						
47-1							2/27	044	14.2	3/30	037	11.9						
48-1							2/29	041	9.0	3/29	033	8.5						
49-1							2/27	048	11.1	3/31	045	11.2						
50-1							3/02	046	12.0	3/30	054	14.1						
51-1							2/25	041	11.5	3/29	042	12.5						
52-1							3/03	041	10.7	3/29	035	10.3						
53-1							2/27	040	10.7	3/29	033	9.0						
54-1							2/25	054	15.7	4/02	067	18.3						
55-1							2/25	032	5.6	3/26	036	10.0						
56-1							2/22	038	8.1	3/20	041	11.4	4/30	000	0.0			
57-1							2/26	040	10.0	3/30	033	10.9						
58-1							3/03	027	7.9	4/01	023	7.9						
59-1							2/25	038	9.6	3/30	029	8.9						
60-1							3/04	040	9.9	3/28	025	6.9						
61-1							2/27	034	8.0	3/29	023	6.1						
62-1							2/25	031	8.5	3/29	032	9.4						
63-1							2/25	019	5.9	3/31	010	3.4						
64-1							2/29	030	8.1	3/30	037	10.6						
65-1							3/01	39	13.2	3/30	36	12.0						
66-1							2/25	32	8.8	3/28	23	7.6						
67-1							2/28	36	9.8	3/30	35	10.9						
68-1							2/28	019	6.1	3/28	011	4.5						
69-1							2/27	40	11.8	3/27	29	10.3						
70-1							3/03	31	6.5	3/25	27	7.1						
71-1							2/28	33	10.4	4/01	34	11.2						
72-1							3/03	43	14.5	3/30	26	9.4						
73-1							2/26	20	5.3	3/30	15	4.6						
74-1							2/26	34	9.8	4/02	31	10.5						
75-1							2/28	39	10.0	3/26	40	10.5						
76-1							2/28	38	7.3	3/28	27	7.9						
77-1							2/26	9	1.4	3/30	12	2.8						
78-1							2/28	35	9.0	3/29	19	5.6						
79-1							2/26	30	6.3	3/29	24	9.4						

Table A-9. (continued)

80-1					2/27	19	4.4	3/29	23	6.4				
81-1					2/26	20	5.8	3/29	8	3.3				
82-1					2/27	33	9.6	3/27	33	10.0				
83-1					2/26	25	6.0	3/29	18	5.1				
84-1					2/28	16	3.3	3/31	8	1.4				
85-1					3/01	34	8.0	3/30	29	7.2				
86-1					2/27	22	3.8	3/28	10	1.7				
87-1					3/07	24	3.6	3/31	19	4.4				
88-1					3/02	18	4.2	3/31	18	4.6				
89-1					2/25	27	6.0	4/02	26	8.2				
56-2								4/13	022	7.6				
FIRST OF MONTH MEASUREMENTS														
average depth and swe :														
						33	8.5		28	8.2	0	0.0		
years	0	0	0	0		44	44		44	44	1	1	0	0
1961-1985 average :														
						30	7.9		24	7.3				
years	0	0	0	0		25	25		25	25	0	0	0	0
MID-MONTH MEASUREMENTS														
average depth and swe :														
									22	7.6				
years	0	0	0	0	0	0			1	1	0	0	0	0
1961-1985 average :														
years	0	0	0	0	0	0			0	0	0	0	0	0

Table A-10. Historical Water Year precipitation at Park Headquarters, West Glacier, MT.

Station : 8809, WEST GLACIER
Unit = inches

yr	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep	SUM
37	0.91	0.27	4.02	2.40	2.99	0.64	3.25	2.03	3.10	0.72	0.99	1.53	22.85
38	2.61	3.89	3.82	2.30	1.95	0.68	1.67	3.73	2.07	1.59	1.90	0.79	27.00
39	2.71	2.41	4.68	3.49	2.08	1.32	0.99	1.88	4.15	0.79	0.29	1.39	26.18
40	0.81	1.57	3.37	1.32	5.87	2.00	2.62	1.65	1.72	1.56	0.06	1.99	24.54
41	2.01	3.53	2.92	2.91	0.46	0.51	0.39	3.50	1.71	0.75	0.48	3.78	22.95
42	1.53	3.19	3.01	0.74	1.46	0.94	2.10	4.29	3.87	2.33	0.62	1.73	25.81
43	2.29	3.71	3.36	2.61	2.66	1.62	1.21	2.38	3.69	0.50	0.36	0.74	25.13
44	3.65	0.94	1.48	0.67	0.88	1.36	1.32	2.62	2.00	0.70	1.98	2.74	20.34
45	0.27	2.55	1.50	2.62	1.86	2.58	2.59	2.12	3.16	0.20	0.45	4.19	24.09
46	4.18	4.22	2.11	3.96	1.78	1.33	2.05	3.12	3.77	1.78	1.15	2.09	31.54
47	5.43	6.75	3.98	4.01	1.89	2.54	1.45	0.76	6.00	0.95	4.73	1.54	40.03
48	4.08	1.94	1.69	2.27	3.05	1.47	4.50	2.86	3.90	3.79	0.67	0.39	30.61
49	0.94	3.70	3.53	1.29	4.20	1.56	1.08	2.27	2.12	1.93	0.55	1.61	24.78
50	3.45	2.73	3.86	4.71	2.32	3.46	1.63	0.91	3.52	1.02	1.78	1.10	30.49
51	5.87	2.35	5.17	4.77	4.88	1.89	1.67	3.08	2.92	1.75	2.59	4.00	40.94
52	4.92	2.25	4.25	2.51	1.29	1.13	0.27	3.17	4.56	1.56	1.44	1.94	29.29
53	0.08	0.68	2.43	7.07	3.24	1.62	3.19	2.99	3.95	0.09	1.17	0.60	27.11
54	0.89	2.73	4.78	4.98	2.69	2.47	2.91	2.13	3.60	3.15	5.14	1.64	37.11
55	1.70	2.94	1.79	1.58	2.33	1.55	1.49	1.82	2.75	4.10	0.00	2.25	24.30
56	5.08	3.55	2.80	2.50	2.50	1.94	1.89	1.09	2.66	1.53	1.67	1.77	28.98
57	3.27	1.05	4.78	2.60	3.67	1.60	1.58	1.62	3.99	0.73	0.69	0.35	25.93
58	2.68	1.36	3.57	3.04	3.29	1.41	3.45	1.40	3.36	0.97	0.62	3.87	29.02
59	1.80	5.64	3.38	5.31	2.29	1.49	2.62	3.05	2.33	0.05	1.55	4.08	33.59
60	2.69	7.52	1.15	2.63	2.33	2.06	2.14	3.65	1.96	0.00	2.75	0.59	29.47
61	1.70	4.52	1.84	2.20	4.73	2.12	2.57	3.29	0.88	2.20	0.76	3.33	30.14
62	1.75	2.18	4.05	1.68	1.40	2.97	2.53	3.33	0.76	0.58	1.03	1.65	23.91
63	3.01	3.96	2.96	2.24	3.54	2.25	1.39	1.16	6.64	1.70	0.79	1.80	31.44
64	1.88	3.03	1.93	3.74	1.33	3.68	1.50	4.62	4.81	3.50	1.51	2.71	34.24
65	2.28	4.28	7.42	3.91	3.63	0.47	3.33	1.06	3.79	2.25	4.12	3.03	39.57
66	0.71	2.14	1.78	3.66	1.59	2.27	0.52	1.56	6.35	1.77	1.69	0.75	24.79
67	2.69	4.35	5.03	5.43	1.66	1.51	0.62	1.15	1.94	0.11	0.17	0.70	25.36
68	4.03	2.48	2.83	1.97	2.58	1.57	1.15	4.94	3.22	0.86	3.66	6.17	35.46
69	4.16	2.38	4.04	6.67	0.66	0.71	1.61	1.90	4.55	0.48	0.01	3.20	30.37
70	1.98	1.16	1.64	5.31	3.56	1.97	1.38	3.41	3.73	1.73	0.70	3.21	29.78
71	1.93	4.74	3.72	5.55	2.14	2.28	0.95	2.84	5.94	1.75	1.91	1.24	34.99
72	2.88	3.77	4.90	5.13	5.07	2.76	1.57	2.13	2.69	1.99	1.60	1.62	36.11
73	1.05	1.20	4.83	2.48	1.07	1.26	1.59	2.09	2.32	2.27	1.14	2.62	23.92
74	2.59	4.63	3.27	5.77	2.98	2.87	2.47	2.18	2.24	1.37	1.12	1.32	32.81
75	0.14	4.53	2.52	4.45	2.58	1.67	1.17	2.19	2.54	2.00	4.06	1.14	28.99
76	4.17	2.81	3.78	3.75	3.08	0.96	1.88	2.83	3.29	3.05	4.09	0.80	34.49
77	0.30	1.22	1.91	1.29	1.40	2.16	0.33	2.13	0.75	3.13	2.55	3.24	20.41
78	1.17	2.70	6.02	2.83	1.06	0.51	2.43	3.68	2.12	3.04	4.48	1.64	31.68
79	0.64	2.14	2.56	1.05	3.59	1.23	2.23	2.66	1.47	1.12	0.85	0.80	20.34
80	2.37	0.65	2.64	2.26	2.04	1.15	1.24	3.96	2.49	1.62	2.37	2.27	25.06
81	0.86	2.89	7.72	1.32	2.46	1.32	2.55	3.96	6.83	1.67	1.70	1.14	34.42
82	0.90	2.76	2.43	4.10	5.10	1.43	2.66	1.40	2.48	2.58	0.89	2.12	28.85
83	1.80	3.48	3.62	4.36	1.41	1.90	1.43	0.96	4.41	4.70	0.52	1.41	30.00
84	1.56	3.80	2.72	3.02	1.01	2.07	2.16	3.54	2.83	0.42	0.73	3.61	27.47
85	3.36	3.46	3.19	0.16	1.65	1.32	1.16	1.75	1.60	0.09	2.08	4.83	24.65
86	2.52	3.00	0.81	3.41	1.90	1.37	0.97	2.55	3.44	3.02	0.54	3.49	27.02
87	1.16	3.97	0.65	1.40	1.33	3.17	1.29	1.96	2.04	3.32	2.20	0.33	22.82
88	0.22	1.17	2.27	1.94	2.41	1.87	1.64	3.33	1.93	0.22	0.36	1.83	19.19
all years													
ave	2.26	2.98	3.28	3.14	2.48	1.73	1.82	2.51	3.17	1.64	1.56	2.09	28.66
yrs	(52)	(52)	(52)	(52)	(52)	(52)	(52)	(52)	(52)	(52)	(52)	(52)	(52)
1961-1985 average :													
	2.00	3.01	3.57	3.37	2.45	1.78	1.70	2.59	3.23	1.84	1.78	2.25	29.57
yrs	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)

Table A-11. Historical Water Year precipitation at Park Headquarters, West Glacier, MT ranked in declining amount.

Weight: 1.00 Station: 8809, WEST GLACIER

Start Yr. 37 End Yr. 88
weights for months:
October - 1.00
November - 1.00
December - 1.00
January - 1.00
February - 1.00
March - 1.00
April - 1.00
May - 1.00

Year (wt.)	INDEX TOTAL
37	16.51
38	20.65
39	19.56
40	19.21
41	16.23
42	17.26
43	19.84
44	12.92
45	16.09
46	22.75
47	26.81
48	21.86
49	18.57
50	23.07
51	29.68
52	19.79
53	21.30
54	23.58
55	15.20
56	21.35
57	20.17
58	20.20
59	25.58
60	24.17
61	22.97
62	19.89
63	20.81
64	21.71
65	26.38
66	14.23
67	22.44
68	21.55
69	22.13
70	20.41
71	24.15
72	28.21
73	15.57
74	26.76
75	19.25
76	23.26
77	10.74
78	20.40
79	16.10
80	16.31
81	23.08
82	20.78
83	18.96
84	19.83
85	16.05
86	16.53
87	14.73
88	14.85
AVERAGE	20.2
MAXIMUM	29.7
MINIMUM	10.7

****

number of values = 52
arithmetic average = 20.20 log average = 1.297
std. deviation = 4.00 log std. dev. = 0.090
coeff of variation = 0.20 log coef. var. = 0.069
arithmetic skew = 0.065 log skew = -0.524

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	10.90	12.25	11.34
95.00	1.053	13.62	14.10	13.71
90.00	1.111	15.07	15.20	15.06
80.00	1.250	16.83	16.64	16.76
50.00	2.000	20.20	19.80	20.15
20.00	5.000	23.57	23.55	23.62
10.00	10.000	25.32	25.79	25.42
5.00	20.000	26.78	27.80	26.88
1.00	100.000	29.50	31.99	29.52

Table A-12. Prefire season (October - May) historical precipitation at Park Headquarters, West Glacier, MT ranked in declining amount.

Gage No. Station : 2809,WEST GLACIER

for the months October - May

Ranks #	Water Year	Value inches	Weibull plot pos.	Value log10
1	51	29.68	0.019	1.472
2	72	28.21	0.038	1.450
3	47	26.81	0.057	1.428
4	74	26.76	0.075	1.427
5	65	26.38	0.094	1.421
6	59	25.58	0.113	1.408
7	60	24.17	0.132	1.383
8	71	24.15	0.151	1.383
9	54	23.58	0.170	1.373
10	76	23.26	0.189	1.367
11	81	23.08	0.208	1.363
12	50	23.07	0.226	1.363
13	61	22.97	0.245	1.361
14	46	22.75	0.264	1.357
15	67	22.44	0.283	1.351
16	69	22.13	0.302	1.345
17	48	21.86	0.321	1.340
18	64	21.71	0.340	1.337
19	68	21.55	0.358	1.333
20	56	21.35	0.377	1.329
21	53	21.30	0.396	1.328
22	82	20.78	0.415	1.318
23	38	20.65	0.434	1.315
24	63	20.51	0.453	1.312
25	70	20.41	0.472	1.310
26	78	20.40	0.491	1.310
27	58	20.20	0.509	1.305
28	57	20.17	0.528	1.305
29	62	19.89	0.547	1.299
30	84	19.88	0.566	1.298
31	43	19.84	0.585	1.298
32	52	19.79	0.604	1.296
33	39	19.56	0.623	1.291
34	75	19.25	0.642	1.284
35	40	19.21	0.660	1.284
36	83	18.96	0.679	1.278
37	49	18.57	0.698	1.269
38	42	17.26	0.717	1.237
39	86	16.53	0.736	1.218
40	37	16.51	0.755	1.218
41	80	16.31	0.774	1.212
42	41	16.23	0.792	1.210
43	79	16.10	0.811	1.207
44	45	16.09	0.830	1.207
45	55	16.05	0.849	1.205
46	73	15.57	0.868	1.192
47	55	15.20	0.887	1.182
48	87	14.93	0.906	1.174
49	88	14.85	0.925	1.172
50	66	14.23	0.943	1.153
51	44	12.92	0.962	1.111
52	77	10.74	0.981	1.031

number of values = 52
arithmetic average = 20.20log average = 1.297

std. deviation = 4.00log std. dev. = 0.090
coeff of variation = 0.20log cof. var. = 0.069
arithmetic skew = 0.065log skew = -0.524

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	10.90	12.25	11.34
95.00	1.053	13.62	14.10	13.71
90.00	1.111	15.07	15.20	15.06
80.00	1.250	16.83	16.64	16.76
50.00	2.000	20.20	19.80	20.15
20.00	5.000	23.57	23.55	23.62
10.00	10.000	25.32	25.79	25.42
5.00	20.000	26.78	27.80	26.88
1.00	100.000	29.50	31.99	29.52

Table A-13. Fire season (June - August) historical precipitation at Park Headquarters, West Glacier, MT.

Weight: 1.00 Station: 8809, WEST GLACIER

Start Yr. 37 End Yr. 88

Year	June (Wt.) (1.00)	July (1.00)	August (1.00)	INDEX TOTAL
37	3.10	0.72	0.99	4.81
38	2.07	1.59	1.90	5.56
39	4.15	0.79	0.29	5.23
40	1.72	1.56	0.06	3.34
41	1.71	0.75	0.48	2.94
42	3.87	2.33	0.62	6.82
43	3.69	0.50	0.36	4.55
44	2.00	0.70	1.98	4.68
45	3.16	0.20	0.45	3.81
46	3.77	1.78	1.15	6.70
47	6.00	0.95	4.73	11.68
48	3.90	3.79	0.67	8.36
49	2.12	1.93	0.55	4.60
50	3.52	1.02	1.78	6.32
51	2.92	1.75	2.59	7.26
52	4.56	1.56	1.44	7.56
53	3.95	0.09	1.17	5.21
54	3.60	3.15	5.14	11.89
55	2.75	4.10	0.00	6.85
56	2.66	1.53	1.67	5.86
57	3.99	0.73	0.69	5.41
58	3.36	0.97	0.62	4.95
59	2.33	0.05	1.55	3.93
60	1.96	0.00	2.75	4.71
61	0.88	2.20	0.76	3.84
62	0.76	0.58	1.03	2.37
63	6.64	1.70	0.79	9.13
64	4.81	3.50	1.51	9.82
65	3.79	2.25	4.12	10.16
66	6.35	1.77	1.69	9.81
67	1.94	0.11	0.17	2.22
68	3.22	0.86	3.66	7.74
69	4.55	0.48	0.01	5.04
70	3.73	1.73	0.70	6.16
71	5.94	1.75	1.91	9.60
72	2.69	1.99	1.60	6.28
73	2.32	2.27	1.14	5.73
74	2.24	1.37	1.12	4.73
75	2.54	2.00	4.06	8.60
76	3.29	3.05	4.09	10.43
77	0.75	3.13	2.55	6.43
78	2.12	3.04	4.48	9.64
79	1.47	1.12	0.85	3.44
80	2.49	1.62	2.37	6.48
81	6.83	1.67	1.70	10.20
82	2.48	2.58	0.89	5.95
83	4.41	4.70	0.52	9.63
84	2.83	0.42	0.73	3.98
85	1.60	0.09	2.08	3.77
86	3.44	3.02	0.54	7.00
87	2.04	3.32	2.20	7.56
88	1.93	0.22	0.36	2.51

AVERAGE	6.37
MAXIMUM	11.89
MINIMUM	2.22

****

number of values = 52
arithmetic average = 6.37 log average = 0.769
std. deviation = 2.50 log std. dev. = 0.181
coeff of variation = 0.39 log cof. var. = 0.235
arithmetic skew = 0.423 log skew = -0.374

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	0.56	2.23	1.99
95.00	1.053	2.26	2.96	2.84
90.00	1.111	3.17	3.45	3.40
80.00	1.250	4.27	4.14	4.18
50.00	2.000	6.37	5.88	6.03
20.00	5.000	8.47	8.35	8.39
10.00	10.000	9.57	10.03	9.83
5.00	20.000	10.48	11.67	11.13
1.00	100.000	12.16	15.50	13.81

Table A-14. Fire Season (June-August) historical precipitation at Park Headquarters, West Glacier, MT ranked in declining amount.

Gage No. Station : 8809,WEST GLACIER

Ranks #	WY #	Jun inches	Jul inches	Aug inches	Total inches	Weibull plotpos	Value log10
1	54	3.60	3.15	5.14	11.89	0.019	1.075
2	47	6.00	0.95	4.73	11.68	0.038	1.067
3	76	3.29	3.05	4.09	10.43	0.057	1.018
4	81	6.83	1.67	1.70	10.20	0.075	1.009
5	65	3.79	2.25	4.12	10.16	0.094	1.007
6	64	4.81	3.50	1.51	9.82	0.113	0.992
7	66	6.35	1.77	1.69	9.81	0.132	0.992
8	78	2.12	3.04	4.48	9.64	0.151	0.984
9	83	4.41	4.70	0.52	9.63	0.170	0.984
10	71	5.94	1.75	1.91	9.60	0.189	0.982
11	63	6.64	1.70	0.79	9.13	0.208	0.960
12	75	2.54	2.00	4.06	8.60	0.226	0.934
13	48	3.90	3.79	0.67	8.36	0.245	0.922
14	68	3.22	0.86	3.66	7.74	0.264	0.889
15	87	2.04	3.32	2.20	7.56	0.283	0.879
16	52	4.56	1.56	1.44	7.56	0.302	0.879
17	51	2.92	1.75	2.59	7.26	0.321	0.861
18	86	3.44	3.02	0.54	7.00	0.340	0.845
19	55	2.75	4.10	0.00	6.85	0.358	0.836
20	42	3.87	2.33	0.62	6.82	0.377	0.834
21	46	3.77	1.78	1.15	6.70	0.396	0.826
22	80	2.49	1.62	2.37	6.48	0.415	0.812
23	77	0.75	3.13	2.55	6.43	0.434	0.808
24	50	3.52	1.02	1.78	6.32	0.453	0.801
25	72	2.69	1.99	1.60	6.28	0.472	0.798
26	70	3.73	1.73	0.70	6.16	0.491	0.790
27	82	2.48	2.58	0.89	5.95	0.509	0.775
28	56	2.66	1.53	1.67	5.86	0.528	0.768
29	73	2.32	2.27	1.14	5.73	0.547	0.758
30	38	2.07	1.59	1.90	5.56	0.566	0.745
31	57	3.99	0.73	0.69	5.41	0.585	0.733
32	39	4.15	0.79	0.29	5.23	0.604	0.719
33	53	3.95	0.09	1.17	5.21	0.623	0.717
34	69	4.55	0.48	0.01	5.04	0.642	0.702
35	58	3.36	0.97	0.62	4.95	0.660	0.695
36	37	3.10	0.72	0.99	4.81	0.679	0.682
37	74	2.24	1.37	1.12	4.73	0.698	0.675
38	60	1.96	0.00	2.75	4.71	0.717	0.673
39	44	2.00	0.70	1.98	4.68	0.736	0.670
40	49	2.12	1.93	0.55	4.60	0.755	0.663
41	43	3.69	0.50	0.36	4.55	0.774	0.658
42	84	2.83	0.42	0.73	3.98	0.792	0.600
43	59	2.33	0.05	1.55	3.93	0.811	0.594
44	61	0.88	2.20	0.76	3.84	0.830	0.584
45	45	3.16	0.20	0.45	3.81	0.849	0.581
46	85	1.60	0.09	2.08	3.77	0.868	0.576
47	79	1.47	1.12	0.85	3.44	0.887	0.537
48	40	1.72	1.56	0.06	3.34	0.906	0.524
49	41	1.71	0.75	0.48	2.94	0.925	0.468
50	88	1.93	0.22	0.36	2.51	0.943	0.400
51	62	0.76	0.58	1.03	2.37	0.962	0.375
52	67	1.94	0.11	0.17	2.22	0.981	0.346

number of values = 52
arithmetic average = 6.37 log average = 0.769

std. deviation = 2.50 log std. dev. = 0.181
coeff of variation = 0.39 log cof. var. = 0.235
arithmetic skew = 0.423 log skew = -0.374

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	0.56	2.23	1.99
95.00	1.053	2.26	2.96	2.84
90.00	1.111	3.17	3.45	3.40
80.00	1.250	4.27	4.14	4.18
50.00	2.000	6.37	5.88	6.03
20.00	5.000	8.47	8.35	8.39
10.00	10.000	9.57	10.03	9.83
5.00	20.000	10.48	11.67	11.13
1.00	100.000	12.18	15.50	13.81

Table A-15. Extended fire season (June - September) historical precipitation at Park Headquarters, West Glacier, MT.

Weight: 1.00 Station: 8809, WEST GLACIER

Start Yr. 37 End Yr. 88

Year	June (Wt.) (1.00)	July (1.00)	August (1.00)	September (1.00)	INDEX TOTAL
37	3.10	0.72	0.99	1.53	6.34
38	2.07	1.59	1.90	0.79	6.35
39	4.15	0.79	0.29	1.39	6.62
40	1.72	1.56	0.06	1.99	5.33
41	1.71	0.75	0.48	3.78	6.72
42	3.87	2.33	0.62	1.73	8.55
43	3.69	0.50	0.36	0.74	5.29
44	2.00	0.70	1.98	2.74	7.42
45	3.16	0.20	0.45	4.19	8.00
46	3.77	1.78	1.15	2.09	8.79
47	6.00	0.95	4.73	1.54	13.22
48	3.90	3.79	0.67	0.39	8.75
49	2.12	1.93	0.55	1.61	6.21
50	3.52	1.02	1.78	1.10	7.42
51	2.92	1.75	2.59	4.00	11.26
52	4.56	1.56	1.44	1.94	9.50
53	3.95	0.09	1.17	0.60	5.81
54	3.60	3.15	5.14	1.64	13.53
55	2.75	4.10	0.00	2.25	9.10
56	2.66	1.53	1.67	1.77	7.63
57	3.99	0.73	0.69	0.35	5.76
58	3.36	0.97	0.62	3.87	8.82
59	2.33	0.05	1.55	4.08	8.01
60	1.96	0.00	2.75	0.59	5.30
61	0.88	2.20	0.76	3.33	7.17
62	0.76	0.58	1.03	1.65	4.02
63	6.64	1.70	0.79	1.80	10.93
64	4.81	3.50	1.51	2.71	12.53
65	3.79	2.25	4.12	3.03	13.19
66	6.35	1.77	1.69	0.75	10.56
67	1.94	0.11	0.17	0.70	2.92
68	3.22	0.86	3.66	6.17	13.91
69	4.55	0.48	0.01	3.20	8.24
70	3.73	1.73	0.70	3.21	9.37
71	5.94	1.75	1.91	1.24	10.84
72	2.69	1.99	1.60	1.62	7.90
73	2.32	2.27	1.14	2.62	8.35
74	2.24	1.37	1.12	1.32	6.05
75	2.54	2.00	4.06	1.14	9.74
76	3.29	3.05	4.09	0.80	11.23
77	0.75	3.13	2.55	3.24	9.67
78	2.12	3.04	4.48	1.64	11.28
79	1.47	1.12	0.85	0.80	4.24
80	2.49	1.62	2.37	2.27	8.75
81	6.83	1.67	1.70	1.14	11.34
82	2.48	2.58	0.89	2.12	8.07
83	4.41	4.70	0.52	1.41	11.04
84	2.83	0.42	0.73	3.61	7.59
85	1.60	0.09	2.08	4.83	8.60
86	3.44	3.02	0.54	3.49	10.49
87	2.04	3.32	2.20	0.33	7.89
88	1.93	0.22	0.36	1.83	4.34
				AVERAGE	8.46
				MAXIMUM	13.91
				MINIMUM	2.92

****

number of values = 52
arithmetic average = 8.46 log average = 0.905
std. deviation = 2.60 log std. dev. = 0.145
coeff of variation = 0.31 log coef. var. = 0.161
arithmetic skew = 0.156 log skew = -0.701

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	2.42	3.69	3.12
95.00	1.053	4.19	4.63	4.37
90.00	1.111	5.13	5.23	5.14
80.00	1.250	6.28	6.06	6.17
50.00	2.000	8.46	8.04	8.36
20.00	5.000	10.65	10.66	10.71
10.00	10.000	11.79	12.35	11.95
5.00	20.000	12.73	13.95	12.95
1.00	100.000	14.50	17.52	14.72

Table A-16. Extended fire season (June - September) historical precipitation at Park Headquarters, West Glacier, MT ranked in declining amount.

Gage No. Station : 8809,WEST GLACIER

Ranks #	WY #	Jun inches	Jul inches	Aug inches	Sep inches	Total inches	Weibull plotpos	Value log10
1	68	3.22	0.86	3.66	6.17	13.91	0.019	1.143
2	54	3.60	3.15	5.14	1.64	13.53	0.038	1.131
3	47	6.00	0.95	4.73	1.54	13.22	0.057	1.121
4	65	3.79	2.25	4.12	3.03	13.19	0.075	1.120
5	64	4.81	3.50	1.51	2.71	12.53	0.094	1.098
6	81	6.83	1.67	1.70	1.14	11.34	0.113	1.055
7	78	2.12	3.04	4.48	1.64	11.28	0.132	1.052
8	51	2.92	1.75	2.59	4.00	11.26	0.151	1.052
9	76	3.29	3.05	4.09	0.80	11.23	0.170	1.050
10	83	4.41	4.70	0.52	1.41	11.04	0.189	1.043
11	63	6.64	1.70	0.79	1.80	10.93	0.208	1.039
12	71	5.94	1.75	1.91	1.24	10.84	0.226	1.035
13	66	6.35	1.77	1.69	0.75	10.56	0.245	1.024
14	86	3.44	3.02	0.54	3.49	10.49	0.264	1.021
15	75	2.54	2.00	4.06	1.14	9.74	0.283	0.989
16	77	0.75	3.13	2.55	3.24	9.67	0.302	0.985
17	52	4.56	1.56	1.44	1.94	9.50	0.321	0.978
18	70	3.73	1.73	0.70	3.21	9.37	0.340	0.972
19	55	2.75	4.10	0.00	2.25	9.10	0.358	0.959
20	58	3.36	0.97	0.62	3.87	8.82	0.377	0.945
21	46	3.77	1.78	1.15	2.09	8.79	0.396	0.944
22	80	2.49	1.62	2.37	2.27	8.75	0.415	0.942
23	48	3.90	3.79	0.67	0.39	8.75	0.434	0.942
24	85	1.60	0.09	2.08	4.83	8.60	0.453	0.934
25	42	3.87	2.33	0.62	1.73	8.55	0.472	0.932
26	73	2.32	2.27	1.14	2.62	8.35	0.491	0.922
27	69	4.55	0.48	0.01	3.20	8.24	0.509	0.916
28	82	2.48	2.58	0.89	2.12	8.07	0.528	0.907
29	59	2.33	0.05	1.55	4.08	8.01	0.547	0.904
30	45	3.16	0.20	0.45	4.19	8.00	0.566	0.903
31	72	2.69	1.99	1.60	1.62	7.90	0.585	0.898
32	87	2.04	3.32	2.20	0.33	7.89	0.604	0.897
33	56	2.66	1.53	1.67	1.77	7.63	0.623	0.883
34	84	2.83	0.42	0.73	3.61	7.59	0.642	0.880
35	50	3.52	1.02	1.78	1.10	7.42	0.660	0.870
36	44	2.00	0.70	1.98	2.74	7.42	0.679	0.870
37	61	0.88	2.20	0.76	3.33	7.17	0.698	0.856

Table A-16. (continued)

38	41	1.71	0.75	0.48	3.78	6.72	0.717	0.827
39	39	4.15	0.79	0.29	1.39	6.62	0.736	0.821
40	38	2.07	1.59	1.90	0.79	6.35	0.755	0.803
41	37	3.10	0.72	0.99	1.53	6.34	0.774	0.802
42	49	2.12	1.93	0.55	1.61	6.21	0.792	0.793
43	74	2.24	1.37	1.12	1.32	6.05	0.811	0.782
44	53	3.95	0.09	1.17	0.60	5.81	0.830	0.764
45	57	3.99	0.73	0.69	0.35	5.76	0.849	0.760
46	40	1.72	1.56	0.06	1.99	5.33	0.868	0.727
47	60	1.96	0.00	2.75	0.59	5.30	0.887	0.724
48	43	3.69	0.50	0.36	0.74	5.29	0.906	0.723
49	88	1.93	0.22	0.36	1.83	4.34	0.925	0.637
50	79	1.47	1.12	0.85	0.80	4.24	0.943	0.627
51	62	0.76	0.58	1.03	1.65	4.02	0.962	0.604
52	67	1.94	0.11	0.17	0.70	2.92	0.981	0.465

number of values = 52
arithmetic average = 8.46log average = 0.905

std. deviation = 2.60log std. dev. = 0.145
coeff of variation = 0.31log cof. var. = 0.161
arithmetic skew = 0.156log skew = -0.701

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	2.42	3.69	3.12
95.00	1.053	4.19	4.63	4.37
90.00	1.111	5.13	5.23	5.14
80.00	1.250	6.28	6.06	6.17
50.00	2.000	8.46	8.04	8.36
20.00	5.000	10.65	10.66	10.71
10.00	10.000	11.79	12.35	11.95
5.00	20.000	12.73	13.95	12.95
1.00	100.000	14.50	17.52	14.72

Table A-17. Park Headquarters, West Glacier, MT climatological summary.

TAPS Station : WEST GLACIER, 8809
start yr. - 1950 end yr. - 1988

	Temperature						Precipitation			
				2 years in 10 will have		avg		2 yrs in 10 will have		
Month	avg daily max	avg daily min	avg	max temp. >than	min temp. <than	no. of grow'n degree days*	avg (in.)	less than (in.)	more than (in.)	average number of days with 0.10 inch or more
January	27.9	13.9	20.9	46	-24	0	3.45	1.81	4.88	9
February	34.8	18.9	26.8	50	-19	0	2.51	1.50	3.41	7
March	41.6	22.5	32.0	59	-9	8	1.83	1.16	2.43	6
April	52.4	29.4	40.9	74	13	85	1.76	1.00	2.45	5
May	63.8	36.8	50.3	83	24	320	2.48	1.56	3.31	6
June	71.2	43.4	57.3	89	30	518	3.22	1.88	4.42	7
July	79.2	46.8	63.0	93	34	711	1.72	0.55	2.75	4
August	77.8	46.0	61.9	92	34	678	1.75	0.63	2.77	4
September	66.0	38.7	52.3	86	24	372	2.17	0.99	3.18	6
October	52.7	31.6	42.1	72	15	115	2.21	0.83	3.36	6
November	37.3	24.5	30.9	56	-3	9	2.99	1.68	4.15	8
December	30.3	18.3	24.3	47	-16	1	3.36	1.96	4.61	10
Yearly :										
Average	52.9	30.9	41.9	----	----	----	---	---	---	---
Extreme	99	-36	---	95	-29	----	---	---	---	---
Total	---	---	---	----	----	2818	29.44	21.27	35.63	78

*A growing degree day is a unit of heat available for plant growth. It can be calculated by adding the maximum and minumum daily temperatures, dividing the sum by 2, and subtracting the temperature below which growth is minimal for the principal crops in the area (Threshold : 40.0 deg. F)

FROST Station : WEST GLACIER, 8809
start yr. - 1950 end yr. - 1988

	Temperature		
Probability	24F or lower	28F or lower	32F or lower
Last freezing temperature in spring : March-June			
1 year in 10 later than--	May 6	May 30	June 20
2 year in 10 later than--	April 30	May 24	June 14
5 year in 10 later than--	April 21	May 13	June 2
First freezing temperature in fall : August-Nov.			
1 yr in 10 earlier than--	September 22	September 12	August 29
2 yr in 10 earlier than--	September 29	September 17	September 3
5 yr in 10 earlier than--	October 13	September 26	September 11

Table A-18. Historical monthly snow depth and snow water equivalent measurements from Desert Mountain, MT.

Station : 13A02, DESERT MOUNTAIN

Unit = inches

year/	January			February			March			April			May			June		
card	date	dep	swe	date	dep	swe	date	dep	swe	date	dep	swe	date	dep	swe	date	dep	swe
37-1							3/02	050	15.2				5/02	032	13.4			
38-1							3/01	036	10.5				5/02	021	7.6			
39-1				1/31	040	10.0	2/28	047	12.6	4/02	033	13.1	5/01	012	5.5			
40-1				1/30	018	4.0	3/02	040	9.6	4/02	034	11.6	5/02	021	9.7			
41-1				2/01	032	9.7	3/01	028	8.1	3/28	022	7.4	4/30	000	0.0			
42-1										4/01	031	8.5	5/01	004	1.2			
43-1										4/02	052	18.2	5/03	017	7.1			
44-1										3/30	033	8.4	4/29	012	3.3			
45-1										3/28	041	12.3	5/01	042	14.9			
46-1										3/29	041	14.8	5/02	021	10.1			
47-1										3/28	054	20.5	5/01	033	15.3			
48-1							2/26	045	10.1	4/01	051	14.0	4/28	041	15.0			
49-1										3/31	057	18.6	5/02	027	10.8			
50-1	K/30	032	6.4	2/02	047	12.9	2/27	057	16.6	3/31	070	22.9	5/01	051	21.1	6/01	010	4.7
51-1	1/03	039	6.7	1/31	043	11.8	2/28	050	15.5	3/29	059	21.0	4/30	034	13.7			
52-1	K/28	039	9.0	1/30	047	14.7	2/27	051	15.6	3/25	055	17.7	4/28	018	8.1			
53-1	K/29	018	3.4	1/30	037	9.5	2/25	042	11.9	3/30	042	13.1	5/02	036	13.1			
54-1	1/02	026	5.3	2/01	050	14.0	2/25	049	15.6	3/26	051	17.8	5/03	044	17.7	6/01	000	0.0
55-1	1/03	018	2.7	2/02	027	5.4	3/02	042	10.5	4/04	041	14.3	5/02	037	14.3			
56-1	1/03	038	8.5	1/27	049	11.8	3/04	066	18.2	3/26	058	18.7	4/27	037	15.5			
57-1	1/06	030	6.4	2/01	042	9.1	3/05	049	13.5	3/29	049	16.2	4/26	043	15.0			
58-1	K/30	028	6.1	1/27	033	8.2	2/28	044	12.4	3/28	040	14.5	4/25	039	15.8			
59-1	K/31	033	7.6	1/30	051	13.2	2/27	057	16.5	3/27	051	17.6	4/29	039	16.5			
60-1	B/23	030	8.7	1/29	048	12.4	2/25	054	13.9	3/25	046	15.9	4/29	038	15.5			
61-1	K/23	025	6.0	1/27	025	8.8	2/28	044	12.2	3/27	044	14.1	4/24	039	14.6			
62-1	1/02	035	9.5	1/29	040	12.0	2/26	045	13.4	3/26	057	17.0	4/27	030	12.2	6/01	000	0.0
63-1	K/28	018	4.0	1/28	028	6.7	2/26	033	9.4	3/26	033	11.0	5/02	025	9.2	5/29	000	0.0
64-1	K/31	022	5.2	1/31	039	10.8	2/25	041	12.2	3/30	052	17.2	4/27	041	16.5	6/01	003	1.5
65-1	1/04	44	10.3	1/29	56	16.2	2/23	56	20.0	3/29	57	21.8	4/27	43	20.6	5/28	1	0.7
66-1	K/30	23	5.0	1/31	36	10.0	2/25	36	12.5	3/28	40	14.8	4/26	23	10.3	5/31	0	0.0
67-1	K/29	035	9.0	2/01	045	15.0	3/02	049	17.8	3/30	061	20.9	5/01	045	19.7	5/31	000	0.0
68-1	K/28	020	5.4	1/31	035	10.2	3/01	039	12.6	4/02	044	15.6	5/03	028	12.3	5/28	000	0.0
69-1	1/06	30	8.9	1/31	55	15.9	2/28	49	16.9	4/01	44	18.1	5/01	22	9.3			

Table A-18. (continued)

70-1	K/30	15	3.4	1/30	36	8.9	2/27	36	13.3	3/27	44	16.7	5/03	33	16.6	6/01	0	0.0
71-1	K/30	39	9.5	1/29	48	15.0	2/26	48	16.2	4/01	53	20.0	4/29	38	16.0	6/02	0	0.0
72-1	K/29	34	10.5	1/28	51	17.2	3/02	63	21.7	3/30	51	23.3	4/27	46	22.8	6/05	0	0.0
73-1	K/29	30	7.8	1/31	33	9.1	3/01	34	10.7	3/29	40	13.2	5/03	33	11.8	5/30	0	0.0
74-1	K/27	41	10.8	1/31	55	14.6	2/26	67	19.4	3/29	64	22.0	5/02	51	22.0	5/31	30	12.6
75-1	K/30	23	6.0	1/30	33	9.1	2/28	47	15.0	3/28	52	16.4	5/01	44	16.6	5/30	11	5.3
76-1	K/29	22	5.2	1/30	31	9.4	2/27	45	13.5	3/31	49	16.6	4/30	44	16.6	5/28	0	0.0
77-1	1/03	16	3.8	1/27	21	5.2	2/25	27	7.0	3/30	40	11.7	4/29	15	5.9			
78-1	K/23	35	8.1	2/01	48	12.2	3/01	44	15.0	3/30	33	13.1	4/27	27	12.3			
79-1	K/26	27	6.0	1/29	36	8.9	2/26	51	14.0	3/27	51	15.3	5/01	42	16.6	5/30	2	0.9
80-1	K/27	17	3.4	1/29	27	7.1	2/25	37	10.9	3/26	48	14.0	4/26	25	9.9			
81-1	1/06	21	6.2	2/04	25	7.9	2/23	37	10.9	4/01	38	12.2	4/27	25	10.8			
82-1	1/09	31	6.2	2/03	42	10.9	2/25	46	14.9	3/25	53	17.4	4/26	44	18.6	6/01	6	3.2
83-1	1/06	29	8.1	1/25	27	10.1	2/24	32	12.6	3/28	40	12.2	4/28	34	13.1	5/25	4	2.0
84-1	K/28	23	4.6	1/26	26	6.3	2/27	33	8.9	3/29	39	12.5	4/24	26	10.2	5/29	0	0.0
85-1	1/10	38	11.0	1/30	37	11.4	2/25	50	14.3	3/26	52	17.7	5/01	28	12.9			
86-1	1/06	25	5.5	1/28	27	6.8	3/04	32	9.6	3/31	26	9.0	4/26	14	5.2			
87-1	1/01	19	4.8	2/06	32	8.6	3/11	29	10.3	4/03	30	12.0	5/05	0	0.0			
88-1	K/28	12	3.0	1/25	23	4.6	2/24	27	7.9	3/27	42	11.9	4/24	14	4.2			
89-1				2/07	32	8.8	2/23	38	10.5	3/27	44	14.1	4/29	25	10.2			
49-2										4/14	044	17.0	5/16	000	0.0			
50-2													5/12	042	18.3	6/15	000	0.0
52-2										4/14	043	17.1						
54-2													5/14	022	10.0			
56-2										4/18	041	16.7	5/18	019	8.7			
72-2													5/17	20	10.5			
76-2													5/14	0	0.0			
FIRST OF MONTH MEASUREMENTS																		
average depth and swe :																		
		28	6.6		38	10.3		44	13.3		46	15.5		30	12.4		3	1.5
years		39	39		43	43		46	46		51	51		33	53		20	20
1961-1985 average :																		
		28	7.0		37	10.7		44	13.8		47	16.2		34	14.3		3	1.5
years		25	25		25	25		25	25		25	25		25	25		18	18
MID-MONTH MEASUREMENTS																		
average depth and swe :																		
											43	16.9		17	7.9		0	0.0
years		0	0		0	0		0	0		3	3		6	6		1	1
1961-1985 average :																		
														10	5.3			
years		0	0		0	0		0	0		0	0		2	2		0	0

Table A-19. Historical monthly snow depth and snow water equivalent measurements from Emery Creek, MT.

Station : 13A24, EMERY CREEK

Unit = inches

year/	January			February			March			April			May			June		
card	date	dep	swe	date	dep	swe	date	dep	swe	date	dep	swe	date	dep	swe	date	dep	swe
76-1	K/29	19	4.6	1/30	32	9.1	2/27	52	14.3	3/31	51	17.7	4/30	29	11.1	5/28	0	0.0
77-1	1/03	19	3.8	1/27	23	5.4	2/25	27	7.6	3/30	42	11.9	4/29	0	0.0			
78-1	K/23	36	9.0	2/02	55	15.0	2/28	44	14.9	3/30	29	11.3	4/27	14	4.9	6/05	0	0.0
79-1	K/26	30	6.6	1/31	38	10.0	2/26	54	15.8	3/27	49	16.4	5/01	27	13.0	5/30	0	0.0
80-1	K/27	15	2.7	1/29	26	6.1	2/25	32	9.6	3/26	46	11.6	4/26	17	6.6			
81-1	1/06	24	7.4	2/04	29	8.0	2/23	35	11.8	4/01	33	11.2	4/27	15	7.0			
82-1	1/09	40	7.7	2/03	48	12.4	2/25	47	16.3	3/25	47	17.7	4/26	39	15.9	6/01	0	0.0
83-1	1/06	36	10.8	1/25	44	12.3	2/24	40	13.9	3/28	41	12.4	4/28	26	10.6	5/25	0	0.0
84-1	K/28	28	4.8	1/26	30	8.0	2/27	38	10.2	3/29	33	12.0	4/24	18	7.2	5/29	0	0.0
85-1	1/10	44	12.8	1/30	42	12.6	2/25	57	17.6	3/26	49	18.2	5/01	21	9.3	6/01	0	0.0
86-1	1/06	31	5.2	1/28	32	6.9	3/04	38	11.2	3/31	28	9.1	4/26	3	1.6	5/28	0	0.0
87-1				1/30	32	8.9	3/11	38	10.1	4/03	33	12.8	5/04	0	0.0	5/30	0	0.0
88-1	K/28	18	4.8	1/25	28	6.0	2/24	36	9.6	3/27	47	13.1	4/24	8	3.0			
89-1	1/04	37	8.3	2/07	37	10.9	2/23	41	12.0	3/27	44	16.1	4/29	15	7.1			
FIRST OF MONTH MEASUREMENTS																		
average depth and swe :																		
	29	6.8		35	9.4		41	12.5		41	13.7		17	7.0		0	0.0	
years	13	13		14	14		14	14		14	14		14	14		9	9	
1961-1985 average :																		
	29	7.0		37	9.9		43	13.2		42	14.0		21	8.6		0	0.0	
years	10	10		10	10		10	10		10	10		10	10		7	7	

Table A-20. Historical Water Year stream flow measurements from the North Fork of the Flathead River.

Station : 12355500, N FK FLATHEAD NR COLUMBIA FALLS
Unit = acre-ft

Scale = 1000

year	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
11	136	137	69	65	51	60	183	428	643	264	115	92
12	63	46	48	47	38	39	149	445	383	242	105	90
13	74	83	52	40	36	40	176	528	887	270	126	77
14	74	66	50	55	35	40	185	537	439	196	90	82
15	140	175	73	58	45	49	225	328	295	218	103	71
16	84	66	43			127	218	432	1000	682	180	148
17	67	52	48			54	67	612	964	403	102	60
29								511	558	165		
30								437	402	167	87	55
31	54	40	35	34	34	45	150	542	287			
32			32	26	44	93	236	738	738			54
34								903	434	152	73	45
35	49	120	63	64	56				696	282	92	56
36	48	37	24	24	24	34	333	746	327	104	55	40
37	32	25	26	20	21	27	82	556	501	170	73	42
38	50	73	44	47	34	47	271	732	735	242	84	56
39	51	40	33	40	27	49	290	588	334	160	66	46
40	40	39	52	37	35	48	166	529	297	97	50	46
41	51	38	35	32	26	40	168	354	200	94	46	80
42	106	75	140	62	37	35	203	532	514	295	104	67
43	54	52	52	41	41	42	409	473	572	352	105	54
44	46	37	33	25	21	25	77	307	245	94	53	42
45	48	39	31	30	25	30	50	507	503	193	67	53
46	51	74	51	39	34	55	295	829	621	230	89	57
47	69	56	44	31	44	58	275	847	542	214	103	82
48	198	110	59	45	38	36	172	764	673	205	144	62
49	47	38	34	34	31	37	241	754	424	162	84	57
50	86	87	85	52	42	60	130	602	880	446	149	68
51	121	116	111	82	101	69	238	893	599	401	130	135
52	224	102	73	50	44	41	362	664	390	190	87	53
53	40	30	31	53	48	41	132	573	835	335	112	62
54	45	52	47	39	37	41	96	932	846	570	175	122
55	102	90	66	48	32	35	66	396	771	344	110	59
56	125	114	75	59	39	51	241	852	771	275	106	62
57	73	52	46	33	28	41	117	923	483	158	74	44
58	48	46	36	29	33	48	147	826	368	130	68	56
59	71	65	70	70	44	44	240	589	938	336	118	158
60	204	135	99	62	46	81	287	480	702	266	106	64
61	53	53	38	34	48	58	151	762	807	185	80	59
62	79	51	40	33	37	36	284	560	517	183	86	53
63	63	72	70	36	63	57	148	484	548	291	90	59
64	49	47	42	32	30	31	80	639	1027	298	107	81
65	105	69	51	49	43	50	209	641	855	307	126	88
66	73	58	52	48	35	46	195	621	636	257	99	69
67	61	65	61	53	49	45	95	627	931	328	106	56
68	58	70	47	43	56	82	92	543	592	236	102	114
69	118	99	64	54	40	43	365	699	554	243	86	58
70	71	52	39	35	32	33	52	594	647	180	73	54
71	49	37	37	40	86	50	193	854	718	336	131	69
72	59	54	39	32	33	144	191	809	969	360	154	91
73	83	56	47	44	33	38	107	502	474	161	68	50
74	49	107	75	131	67	67	282	703	1236	470	152	79
75	51	45	39	35	28	33	50	475	866	369	128	93

Table A-20. (continued)

76	79	104	141	71	50	45	206	791	482	335	199	86
77	53	44	34	31	27	30	137	329	222	88	66	70
78	51	43	47	36	30	51	191	564	598	280	125	105
79	65	59	39	27	28	52	110	621	454	165	71	48
80	39	33	42	29	28	35	270	682	390	145	85	90
81	63	84	123	120	65	80	230	678	582	296	109	61
82	50	42	36	30	54	55	103	592	766	329	117	67
83	65	53	49	56	40	67	180	545	487	296	119	65
84	50	87	35	68	49	50	169	367	536	212	89	68
85	58	52	36	32	24	31	209	674	472	152	75	102
86	123	152	60	42	51	160	254	521	462	140	69	53
87	67	66	56	33	28	74	280	590	235	120	82	51
88	36	29	31	24	23	34	210	457	352	107	53	39
all years ave	74	68	54	45	40	52	189	609	594	250	100	70
years	(62)	(62)	(63)	(61)	(61)	(62)	(62)	(65)	(66)	(64)	(63)	(64)
1961-1985 average :	64	61	53	48	43	52	172	614	655	260	106	73
years	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)

Table A-21. Historical Water Year stream flow measurements from the North Fork of the Flathead River ranked in declining amount.

Gage No. Station : 12355500/N FK FLATHEAD NR COLUMBIA FALLS

for the months October - September

Ranks #	Water Year	Value acre-ft	Weibull plot pos.	Value log10
1	74	3418000	0.017	6.534
2	54	3002000	0.034	6.477
3	51	2996000	0.051	6.477
4	72	2935000	0.068	6.468
5	56	2770000	0.085	6.442
6	59	2743000	0.102	6.438
7	50	2657000	0.119	6.424
8	71	2600000	0.136	6.415
9	65	2593000	0.153	6.414
10	76	2589000	0.169	6.413
11	60	2532000	0.186	6.403
12	48	2506000	0.203	6.399
13	81	2491000	0.220	6.396
14	67	2477000	0.237	6.394
15	64	2463000	0.254	6.391
16	46	2425000	0.271	6.385
17	69	2423000	0.288	6.384
18	38	2415000	0.305	6.383
19	13	2389000	0.322	6.378
20	47	2365000	0.339	6.374
21	61	2328000	0.356	6.367
22	53	2292000	0.373	6.360
23	52	2280000	0.390	6.358
24	43	2247000	0.407	6.352
25	11	2243000	0.424	6.351
26	82	2241000	0.441	6.350
27	75	2212000	0.458	6.345
28	66	2194000	0.475	6.341
29	42	2170000	0.492	6.336
30	78	2121000	0.508	6.327
31	55	2119000	0.525	6.326
32	86	2087000	0.542	6.320
33	57	2072000	0.559	6.316
34	68	2035000	0.576	6.309
35	83	2022000	0.593	6.306
36	63	1981000	0.610	6.297
37	62	1959000	0.627	6.292
38	49	1943000	0.644	6.288
39	85	1917000	0.661	6.283
40	80	1868000	0.678	6.271
41	70	1862000	0.695	6.270
42	14	1849000	0.712	6.267
43	58	1835000	0.729	6.264
44	36	1796000	0.746	6.254
45	84	1780000	0.763	6.250
46	15	1780000	0.780	6.250
47	79	1739000	0.797	6.240
48	39	1729000	0.814	6.238
49	12	1695000	0.831	6.229
50	87	1682000	0.847	6.226
51	73	1663000	0.864	6.221
52	45	1576000	0.881	6.198
53	37	1575000	0.898	6.197
54	40	1436000	0.915	6.157
55	88	1395000	0.932	6.145
56	41	1164000	0.949	6.066
57	77	1131000	0.966	6.053
58	44	1005000	0.983	6.002

number of values = 58
arithmetic average = 2134690 log average = 6.317

std. deviation = 482708 log std. dev. = 0.105
coeff of variation = 0.23 log cof. var. = 0.017
arithmetic skew = 0.010 log skew = -0.771

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	1011910	1181059	1034645
95.00	1.053	1340635	1393349	1331146
90.00	1.111	1515858	1521689	1502097
80.00	1.250	1728249	1693202	1717694
50.00	2.000	2134690	2077156	2142312
20.00	5.000	2541130	2548177	2557068
10.00	10.000	2753522	2835389	2759969
5.00	20.000	2928745	3093554	2916903
1.00	100.000	3257469	3603145	3179754

Table A-22. Historical Water Year precipitation at Kalispell, MT.

Station : 4558, KALISPELL WSO AP
Unit = inches

yr	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep	SUM
0	1.13	0.92	1.75	0.84	0.99	0.56	1.33	3.90	1.40	0.75	1.48	3.02	18.07
1	0.76	3.74	0.88	1.26	0.84	0.98	0.45	1.95	2.86	0.34	0.14	1.81	16.01
2	0.43	0.73	1.06	0.77	1.67	0.46	0.59	4.50	1.51	2.65	0.95	0.76	16.08
3	0.16	2.95	2.24	0.91	0.48	0.53	0.95	1.07	1.61	1.70	0.78	1.49	14.87
4	1.11	3.13	0.87	1.48	1.90	1.94	0.70	0.79	0.60	0.78	1.15	0.40	14.85
5	0.43	0.26	0.78	1.33	1.21	0.76	0.73	2.73	2.72	0.56	0.11	1.21	12.83
6	1.81	1.54	0.49	1.14	0.41	0.72	0.46	2.68	1.03	0.22	1.98	0.23	12.71
7	0.75	1.79	2.09	2.01	1.51	1.16	0.87	1.06	3.01	1.14	2.54	2.12	20.05
8	0.00	0.50	1.02	1.70	0.81	1.92	0.42	4.21	2.48	1.44	0.88	2.01	17.39
9	1.53	0.35	0.47	1.80	1.11	0.72	0.83	1.47	3.05	3.07	0.11	1.21	15.72
10	0.43	2.99	1.01	0.78	2.06	1.45	0.86	1.67	0.40	0.43	0.67	2.31	15.06
11	1.29	1.68	0.52	0.49	0.48	0.51	0.58	0.96	3.83	0.78	1.44	2.75	15.31
12	0.84	2.49	0.75	1.69	0.48	0.37	0.61	0.76	2.59	1.56	1.03	0.68	13.85
13	0.41	0.83	0.69	2.69	0.33	1.73	0.86	0.92	3.21	0.38	0.61	0.31	12.97
14	1.29	1.16	0.48	1.31	1.68	1.17	1.21	0.60	2.51	0.69	1.31	1.21	14.62
15	3.40	1.58	0.40	1.19	1.01	0.59	1.16	3.51	2.09	2.74	0.22	2.04	19.93
16	0.34	1.66	2.00	1.95	1.06	2.43	0.73	1.11	3.91	1.76	1.96	1.63	20.54
17	0.62	0.80	1.70	1.05	1.82	1.09	1.26	0.97	2.76	0.09	0.32	0.83	13.31
18	0.54	0.51	4.78	1.82		0.76	0.63	0.43	0.58	1.47	0.96	1.59	*****
19	0.91	0.23	0.87	0.72	1.55	0.45	0.24	1.72	0.55	0.88	1.06	0.50	9.68
20	1.05	1.35	0.91	0.85	0.26	0.92	1.48	1.15	0.95	0.98	2.61	0.70	13.21
21	1.25	0.43	1.23	1.29	0.66	1.55	1.17	0.57	1.22	0.62	0.56	0.79	11.34
22	1.15	2.39	1.16	0.74	0.60	0.77	1.86	0.76	0.54	0.81	0.76	0.52	12.06
23	1.05	1.06	1.50	1.07	0.94	0.42	0.41	2.88	1.49	1.60	0.96	0.23	13.61
24	0.55	0.89	1.55	0.91	0.51	0.74	0.01	0.39	3.24	0.97	0.74	0.90	11.40
25	0.32	1.61	2.49	0.88	0.38	1.13	0.87	0.96	2.07	0.58	1.12	2.43	14.84
26	0.69	0.47	0.98	1.15	0.63	0.20	0.21	1.23	1.20	0.20	2.23	2.14	11.33
27	0.67	2.01	1.48	1.31	1.04	0.69	0.41	1.54	1.72	0.77	0.92	2.76	15.32
28	3.17	2.59	1.69	1.15	0.14	0.74	1.80	0.61	2.51	1.49	1.14	0.04	17.07
29	0.82	0.50	1.00	1.97	1.02	0.63	0.64	0.69	0.95	0.31	0.14	0.51	9.18
30	0.51	0.17	2.85	0.80	0.62	0.35	1.32	1.87	2.52	1.02	0.23	2.67	14.93
31	1.61	2.49	0.35	0.55	0.27	0.93	0.25	0.52	1.46	0.70	0.01	2.89	12.03
32	0.44	2.57	1.72	1.18	0.65	1.75	1.06	1.96	0.50	0.68	1.85	0.15	14.51
33	1.35	1.34	0.96	1.10	1.25	0.21	1.43	2.51	1.37	0.21	1.77	1.04	14.54
34	2.70	1.31	3.22	0.88	0.06	2.72	0.68	1.22		0.27	0.07	0.71	*****
35	2.26	0.97	0.94	1.97	0.25	1.18	1.81	1.04	1.03	1.11	0.37	0.14	13.07
36	0.53	1.02	1.02	1.93	2.10	1.50	1.33	0.40	1.73	0.45	0.47	1.04	13.52
37	1.00	0.42	1.68	2.12	1.03	0.44	1.22	1.00	2.16	0.83	0.66	0.91	13.47
38	0.87	1.24	1.23	0.71	1.07	0.94	0.37	1.72	1.17	1.06	0.56	1.14	12.08
39	0.80	1.27	1.13	1.27	0.93	0.84	0.56	1.09	3.80	0.38	0.21	0.96	13.24
40	0.22	0.59	0.94	0.58	2.13	1.10	1.49	1.08	0.83	2.26	0.02	1.69	12.93
41	1.05	2.02	0.81	1.26	0.50	0.54	0.55	1.75	1.51	1.07	0.80	2.04	13.90
42	0.82	1.68	1.05	0.79	1.48	0.49	1.43	3.92	4.13	2.72	0.90	0.31	19.72
43	0.74	2.39	1.51	3.40	0.76	0.90	1.13	1.16	3.33	0.45	0.42	0.23	16.42
44	1.28	0.78	0.28	0.27	0.51	0.84	0.97	1.48	1.46	0.60	1.34	0.75	10.56
45	0.10	1.47	0.63	1.19	0.67	1.37	1.21	1.20	2.82	0.31	0.82	1.57	13.36
46	1.77	0.91	2.12	1.07	0.73	0.55	0.51	1.40	1.81	0.97	0.77	1.30	13.91
47	3.18	1.99	1.82	1.00	0.90	0.90	0.65	1.79	4.56	0.47	3.28	0.99	21.53
48	2.16	1.22	0.81	0.86	1.27	1.24	1.92	4.36	2.76	3.15	2.33	0.10	22.15
49	0.40	1.50	1.02						1.13	1.52	0.58	0.95	*****
50	1.33	1.54	1.06	2.08	1.18	1.87	0.79	0.43	3.56	2.74	1.24	0.54	18.36
51	2.58	0.96	2.11	1.24	1.52	0.44	2.04	2.31	1.81	1.08	2.63	1.88	20.60
52	2.96	0.85	3.11	1.10	0.52	0.68	0.31	1.68	3.26	0.72	1.02	0.12	16.33
53	0.15	0.63	0.96	2.21	0.85	1.01	1.28	1.37	2.93	0.02	1.98	0.44	13.83
54	0.04	0.99	1.50	2.74	0.75	0.69	0.45	1.05	1.98	2.09	3.04	0.81	16.13
55	0.50	0.87	0.32	1.03	1.00	0.47	0.89	1.23	3.06	1.32	0.00	1.55	12.24
56	1.61	2.39	2.36	1.52	1.27	0.89	1.35	1.44	2.92	2.32	1.93	0.92	20.92
57	0.88	0.55	1.08	1.12	1.28	0.49	1.39	1.25	1.87	0.85	0.45	0.20	11.41
58	2.00	0.56	0.98	1.46	1.93	0.72	1.42	1.80	2.20	0.86	0.22	1.84	15.99

Table A-22. (continued)

59	0.60	2.65	2.30	2.03	1.08	0.61	1.22	3.08	1.58	0.04	0.68	3.84	19.71
60	1.97	4.44	0.40	1.30	0.83	1.11	0.82	3.34	0.62	0.03	2.31	0.33	17.50
61	1.00	1.59	0.96	0.75	1.32	1.12	2.01	2.35	0.71	1.20	0.67	2.08	15.76
62	0.92	1.07	2.20	0.97	0.92	1.09	1.05	2.04	0.82	0.16	0.95	0.42	12.61
63	1.25	1.00	0.81	1.61	1.00	1.25	0.88	0.81	3.94	0.95	0.81	1.26	15.57
64	0.67	0.71	1.33	1.24	0.50	1.26	0.60	2.56	3.56	1.69	1.77	1.87	17.76
65	0.95	2.13	4.23	1.84	0.69	0.31	1.44	0.74	2.73	0.85	3.47	1.17	20.55
66	0.11	0.72	0.57	1.61	1.02	0.79	0.65	1.63	4.72	0.37	1.05	0.29	13.53
67	0.88	2.52	1.58	1.75	0.42	1.09	0.59	0.95	2.38	0.07	0.01	0.33	12.57
68	1.60	0.58	1.45	1.01	1.00	0.43	0.26	2.59	2.16	0.46	3.10	3.33	17.97
69	1.50	1.55	2.56	2.97	0.50	0.64	1.30	0.68	3.88	0.10	0.09	1.44	17.21
70	1.07	0.26	1.21	3.11	1.27	0.84	0.68	2.18	2.58	1.59	0.34	0.90	16.03
71	1.20	1.29	1.39	1.81	0.81	0.95	0.44	2.17	3.59	0.93	1.47	0.46	16.51
72	0.95	1.36	1.53	1.58	1.57	1.14	0.86	1.50	1.69	1.51	1.03	0.76	15.48
73	0.84	0.55	1.60	0.69	0.62	0.46	0.47	0.91	1.52	0.05	0.56	0.71	8.98
74	1.19	2.80	1.87	1.94	1.02	1.39	1.92	1.06	1.75	0.64	0.70	1.18	17.46
75	0.12	1.04	1.21	1.95	1.52	1.33	0.83	0.98	1.96	0.98	2.79	0.58	15.29
76	1.67	1.20	1.19	1.36	1.40	0.35	0.97	1.79	1.69	1.64	3.78	0.36	17.40
77	0.38	0.47	0.65	0.81	0.97	1.18	0.43	1.40	0.43	2.57	1.13	2.18	12.60
78	0.13	1.46	3.53	2.30	0.71	0.67	2.37	2.47	0.91	1.50	2.64	0.80	19.49
79	0.07	1.43	0.87	1.42	1.57	0.86	1.49	1.64	0.84	0.67	1.10	0.39	12.35
80	1.45	0.42	1.27	2.15	1.92	0.86	1.52	3.90	2.96	0.81	1.60	0.74	19.60
81	0.78	0.49	2.54	1.44	1.99	1.43	0.94	3.37	3.62	0.72	1.32	0.48	19.12
82	0.20	1.30	1.81	2.66	1.60	0.92	1.32	0.78	4.05	1.59	0.82	1.92	18.97
83	0.52	1.43	1.88	1.09	0.93	1.50	2.18	0.78	3.09	2.06	0.73	1.31	17.50
84	0.83	1.61	1.69	0.78	0.66	1.34	1.53	1.56	1.77	0.51	0.88	1.88	15.04
85	1.85	1.77	1.22	0.20	1.39	0.71	0.58	1.60	1.56	0.23	1.12	3.97	16.20
86	0.92	1.63	0.72	2.22	1.87	0.32	0.83	2.45	2.17	1.42	0.68	2.78	18.01
87	0.51	1.84	0.52	0.66	0.61	2.96	1.19	0.88	1.20	3.98	1.35	0.60	16.30
88	0.05	0.48	1.53	0.97	0.84	0.80	0.94	2.83	1.49	0.87	0.29	2.10	13.24
all years													
ave	1.02	1.37	1.41	1.39	1.01	0.95	0.98	1.67	2.14	1.06	1.12	1.23	15.36
yrs	(89)	(89)	(89)	(88)	(87)	(88)	(88)	(88)	(88)	(89)	(89)	(89)	(86)
1961-1985 average :													
	0.89	1.23	1.65	1.56	1.09	0.96	1.09	1.70	2.36	0.95	1.36	1.23	16.06
yrs	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)

Table A-23. Prefire season (October - May) historical precipitation at Kalispell, MT.

Weight: 1.00 Station: 4558, KALISPELL WSO AP

Start Yr. 0 End Yr. 88
Weights for months:
October - 1.00
November - 1.00
December - 1.00
January - 1.00
February - 1.00
March - 1.00
April - 1.00
May - 1.00

Year (Wt.)	INDEX TOTAL		
0	11.42	56	12.83
1	10.86	57	8.04
2	10.21	58	10.87
3	9.29	59	13.57
4	11.92	60	14.21
5	8.23	61	11.10
6	9.25	62	10.26
7	11.24	63	8.61
8	10.58	64	8.87
9	8.28	65	12.33
10	11.25	66	7.10
11	6.51	67	9.78
12	7.99	68	8.92
13	8.46	69	11.70
14	8.90	70	10.62
15	12.84	71	10.06
16	11.28	72	10.49
17	9.31	73	6.14
18	*****	74	13.19
19	6.69	75	8.98
20	7.97	76	9.93
21	8.15	77	6.29
22	9.43	78	13.64
23	9.35	79	9.35
24	5.55	80	13.49
25	7.64	81	12.98
26	9.58	82	10.59
27	9.15	83	10.31
28	11.89	84	10.00
29	7.27	85	9.32
30	8.49	86	10.96
31	6.97	87	9.17
32	11.35	88	8.49
33	10.15	AVERAGE	9.8
34	12.79	MAXIMUM	14.2
35	10.12	MINIMUM	5.6
36	9.83		
37	8.91		
38	8.15		
39	7.89		
40	8.13		
41	8.48		
42	11.66		
43	11.99		
44	6.41		
45	7.84		
46	9.06		
47	12.23		
48	13.84		
49	*****		
50	10.28		
51	13.20		
52	11.21		
53	8.46		
54	8.21		
55	6.31		

****

number of values = 87
arithmetic average = 9.79 log average = 0.981
std. deviation = 2.08 log std. dev. = 0.096
coeff of variation = 0.21 log coef. var. = 0.097
arithmetic skew = 0.11 log skew = -0.373

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	4.95	5.73	5.40
95.00	1.053	6.37	6.66	6.52
90.00	1.111	7.12	7.21	7.16
80.00	1.250	8.04	7.95	7.99
50.00	2.000	9.79	9.57	9.70
20.00	5.000	11.55	11.51	11.55
10.00	10.000	12.46	12.69	12.56
5.00	20.000	13.22	13.74	13.40
1.00	100.000	14.64	15.96	15.02

Table A-24. Prefire season (October - May) historical precipitation at Kalispell, MT ranked in declining amount.

Gage No. Station : 4558,KALISPELL WSO AP

for the months October - May

Ranks #	Water Year	Value inches	Weibull plot pos.	Value log10
1	60	14.21	0.034	1.153
2	46	13.84	0.045	1.141
3	78	13.64	0.057	1.135
4	59	13.57	0.068	1.133
5	80	13.49	0.080	1.130
6	51	13.20	0.091	1.121
7	74	13.19	0.102	1.120
8	81	12.98	0.114	1.113
9	15	12.84	0.125	1.109
10	56	12.83	0.136	1.108
11	34	12.79	0.148	1.107
12	65	12.33	0.159	1.091
13	47	12.23	0.170	1.087
14	43	11.99	0.182	1.079
15	4	11.92	0.193	1.076
16	25	11.89	0.205	1.075
17	69	11.70	0.216	1.068
18	42	11.66	0.227	1.067
19	0	11.42	0.239	1.058
20	32	11.33	0.250	1.054
21	16	11.26	0.261	1.052
22	10	11.25	0.273	1.051
23	7	11.24	0.284	1.051
24	52	11.21	0.295	1.050
25	61	11.10	0.307	1.045
26	86	10.96	0.318	1.040
27	58	10.87	0.330	1.036
28	1	10.86	0.341	1.036
29	70	10.62	0.352	1.026
30	62	10.59	0.364	1.025
31	8	10.58	0.375	1.024
32	72	10.49	0.386	1.021
33	35	10.42	0.398	1.018
34	83	10.31	0.409	1.013
35	50	10.28	0.420	1.012
36	64	10.26	0.432	1.011
37	2	10.21	0.443	1.009
38	33	10.15	0.455	1.006
39	71	10.06	0.466	1.003
40	24	10.00	0.477	1.000
41	76	9.93	0.489	0.997
42	36	9.83	0.500	0.993
43	67	9.78	0.511	0.990
44	22	9.43	0.523	0.975
45	79	9.35	0.534	0.971
46	23	9.33	0.545	0.970
47	85	9.32	0.557	0.969
48	17	9.31	0.568	0.969
49	3	9.29	0.580	0.968
50	6	9.25	0.591	0.966
51	87	9.17	0.602	0.962
52	27	9.15	0.614	0.961
53	45	9.06	0.625	0.957
54	75	8.98	0.636	0.953
55	68	8.92	0.648	0.950
56	37	8.91	0.659	0.950
57	14	8.90	0.670	0.949
58	54	8.87	0.682	0.948
59	25	8.64	0.693	0.937

Table A-24. (continued)

60	63	8.61	0.705	0.935
61	30	8.49	0.716	0.929
62	38	8.49	0.727	0.929
63	41	8.46	0.739	0.928
64	53	8.46	0.750	0.927
65	13	8.46	0.761	0.927
66	9	8.28	0.773	0.918
67	5	8.23	0.784	0.915
68	54	8.21	0.795	0.914
69	21	8.15	0.807	0.911
70	38	8.15	0.818	0.911
71	40	8.13	0.830	0.910
72	57	8.04	0.841	0.905
73	12	7.99	0.852	0.903
74	20	7.97	0.864	0.901
75	39	7.89	0.875	0.897
76	45	7.84	0.886	0.894
77	29	7.27	0.898	0.862
78	66	7.10	0.909	0.851
79	31	6.97	0.920	0.843
80	19	6.69	0.932	0.825
81	11	6.51	0.943	0.814
82	44	6.41	0.955	0.807
83	55	6.31	0.966	0.800
84	77	6.29	0.977	0.799
85	73	6.14	0.989	0.788
86	26	5.86	1.000	0.745
87	24	5.55	1.011	0.744

number of values = 87
arithmetic average = 9.79log average = 0.981

std. deviation = 2.08log std. dev. = 0.096
coeff of variation = 0.21log coef. var. = 0.097
arithmetic skew = 0.116log skew = -0.373

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	4.95	5.73	5.40
95.00	1.053	6.37	6.66	6.52
90.00	1.111	7.12	7.21	7.16
80.00	1.250	8.04	7.95	7.99
50.00	2.000	9.79	9.57	9.70
20.00	5.000	11.55	11.51	11.55
10.00	10.000	12.46	12.69	12.56
5.00	20.000	13.22	13.74	13.40
1.00	100.000	14.64	15.96	15.02

Table A-25. Fire season (June - August) historical precipitation at Kalispell, MT.

Weight: 1.00 Station: 4558, KALISPELL WSO AP

Start Yr. 0 End Yr. 88

Year (Wt.)	June (1.00)	July (1.00)	August (1.00)	INDEX TOTAL
0	1.40	0.75	1.48	3.63
1	2.86	0.34	0.14	3.34
2	1.51	2.65	0.95	5.11
3	1.61	1.70	0.78	4.09
4	0.60	0.78	1.15	2.53
5	2.72	0.56	0.11	3.39
6	1.03	0.22	1.98	3.23
7	3.01	1.14	2.54	6.69
8	2.48	1.44	0.88	4.80
9	3.05	3.07	0.11	6.23
10	0.40	0.43	0.67	1.50
11	3.83	0.78	1.44	6.05
12	2.59	1.56	1.03	5.18
13	3.21	0.38	0.61	4.20
14	2.51	0.69	1.31	4.51
15	2.09	2.74	0.22	5.05
16	3.91	1.76	1.96	7.63
17	2.76	0.09	0.32	3.17
18	0.58	1.47	0.96	3.01
19	0.55	0.88	1.06	2.49
20	0.95	0.98	2.61	4.54
21	1.22	0.62	0.56	2.40
22	0.54	0.81	0.76	2.11
23	1.49	1.60	0.96	4.05
24	3.24	0.97	0.74	4.95
25	2.07	0.58	1.12	3.77
26	1.20	0.20	2.23	3.63
27	1.72	0.77	0.92	3.41
28	2.51	1.49	1.14	5.14
29	0.95	0.31	0.14	1.40
30	2.52	1.02	0.23	3.77
31	1.46	0.70	0.01	2.17
32	0.50	0.68	1.85	3.03
33	1.37	0.21	1.77	3.35
34	*****	0.27	0.07	*****
35	1.03	1.11	0.37	2.51
36	1.73	0.45	0.47	2.65
37	2.16	0.83	0.66	3.65
38	1.17	1.06	0.56	2.79
39	3.80	0.38	0.21	4.39
40	0.83	2.26	0.02	3.11
41	1.51	1.07	0.80	3.38
42	4.13	2.72	0.90	7.75
43	3.33	0.45	0.42	4.20
44	1.46	0.60	1.34	3.40
45	2.82	0.31	0.82	3.95
46	1.81	0.97	0.77	3.55
47	4.56	0.47	3.28	8.31
48	2.76	3.15	2.33	8.24
49	1.13	1.52	0.58	3.23
50	3.56	2.74	1.24	7.54
51	1.81	1.08	2.63	5.52
52	3.26	0.72	1.02	5.00
53	2.93	0.02	1.98	4.93
54	1.98	2.09	3.04	7.11
55	3.06	1.32	0.00	4.38
56	2.92	2.32	1.93	7.17
57	1.87	0.85	0.45	3.17

Table A-25. (continued)

58	2.20	0.86	0.22	3.28
59	1.58	0.04	0.68	2.30
60	0.62	0.03	2.31	2.96
61	0.71	1.20	0.67	2.58
62	0.82	0.16	0.95	1.93
63	3.94	0.95	0.81	5.70
64	3.56	1.69	1.77	7.02
65	2.73	0.85	3.47	7.05
66	4.72	0.37	1.05	6.14
67	2.38	0.07	0.01	2.46
68	2.16	0.46	3.10	5.72
69	3.88	0.10	0.09	4.07
70	2.58	1.59	0.34	4.51
71	3.59	0.93	1.47	5.99
72	1.69	1.51	1.03	4.23
73	1.52	0.05	0.56	2.13
74	1.75	0.64	0.70	3.09
75	1.96	0.98	2.79	5.73
76	1.69	1.64	3.78	7.11
77	0.43	2.57	1.13	4.13
78	0.91	1.50	2.64	5.05
79	0.84	0.67	1.10	2.61
80	2.96	0.81	1.60	5.37
81	3.62	0.72	1.32	5.66
82	4.05	1.59	0.82	6.46
83	3.09	2.06	0.73	5.88
84	1.77	0.51	0.88	3.16
85	1.56	0.23	1.12	2.91
86	2.17	1.42	0.68	4.27
87	1.20	3.98	1.35	6.53
88	1.49	0.87	0.29	2.65

AVERAGE	4.34
MAXIMUM	8.31
MINIMUM	1.40

****

number of values = 88
arithmetic average = 4.34log average = 0.605
std. deviation = 1.68log std. dev. = 0.173
coeff of variation = 0.39log coef. var. = 0.287
arithmetic skew = 0.541log skew = -0.221

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	0.44	1.59	1.49
95.00	1.053	1.58	2.09	2.04
90.00	1.111	2.19	2.41	2.39
80.00	1.250	2.93	2.88	2.89
50.00	2.000	4.34	4.02	4.08
20.00	5.000	5.76	5.63	5.65
10.00	10.000	6.50	6.71	6.64
5.00	20.000	7.10	7.76	7.56
1.00	100.000	8.25	10.13	9.54

Table A-26. Fire season (June - August) historical precipitation at Kalispell, MT ranked in declining amount.

Gage No. Station : 4558,KALISPELL WSO AP

Ranks #	WY #	Jun inches	Jul inches	Aug inches	Total inches	Weibull plotpos	Value log10
1	47	4.56	0.47	3.28	8.31	0.022	0.920
2	48	2.76	3.15	2.33	8.24	0.034	0.916
3	42	4.13	2.72	0.90	7.75	0.045	0.889
4	16	3.91	1.76	1.96	7.63	0.056	0.883
5	50	3.56	2.74	1.24	7.54	0.067	0.877
6	56	2.92	2.32	1.93	7.17	0.079	0.856
7	54	1.98	2.09	3.04	7.11	0.090	0.852
8	76	1.69	1.64	3.78	7.11	0.101	0.852
9	65	2.73	0.85	3.47	7.05	0.112	0.848
10	64	3.56	1.69	1.77	7.02	0.124	0.846
11	7	3.01	1.14	2.54	6.69	0.135	0.825
12	87	1.20	3.98	1.35	6.53	0.146	0.815
13	82	4.05	1.59	0.82	6.46	0.157	0.810
14	9	3.05	3.07	0.11	6.23	0.169	0.794
15	66	4.72	0.37	1.05	6.14	0.180	0.788
16	11	3.83	0.78	1.44	6.05	0.191	0.782
17	71	3.59	0.93	1.47	5.99	0.202	0.777
18	83	3.09	2.06	0.73	5.88	0.213	0.769
19	75	1.96	0.98	2.79	5.73	0.225	0.758
20	68	2.16	0.46	3.10	5.72	0.236	0.757
21	63	3.94	0.95	0.81	5.70	0.247	0.756
22	81	3.62	0.72	1.32	5.66	0.258	0.753
23	51	1.81	1.08	2.63	5.52	0.270	0.742
24	80	2.96	0.81	1.60	5.37	0.281	0.730
25	12	2.59	1.56	1.03	5.18	0.292	0.714
26	28	2.51	1.49	1.14	5.14	0.303	0.711
27	2	1.51	2.65	0.95	5.11	0.315	0.708
28	15	2.09	2.74	0.22	5.05	0.326	0.703
29	78	0.91	1.50	2.64	5.05	0.337	0.703
30	52	3.26	0.72	1.02	5.00	0.348	0.699
31	24	3.24	0.97	0.74	4.95	0.360	0.695
32	53	2.93	0.02	1.98	4.93	0.371	0.693
33	8	2.48	1.44	0.88	4.80	0.382	0.681
34	20	0.95	0.98	2.61	4.54	0.393	0.657
35	70	2.58	1.59	0.34	4.51	0.404	0.654
36	14	2.51	0.69	1.31	4.51	0.416	0.654
37	39	3.80	0.38	0.21	4.39	0.427	0.642
38	55	3.06	1.32	0.00	4.38	0.438	0.641
39	86	2.17	1.42	0.68	4.27	0.449	0.630
40	72	1.69	1.51	1.03	4.23	0.461	0.626
41	43	3.33	0.45	0.42	4.20	0.472	0.623
42	13	3.21	0.38	0.61	4.20	0.483	0.623
43	77	0.43	2.57	1.13	4.13	0.494	0.616
44	3	1.61	1.70	0.78	4.09	0.506	0.612
45	69	3.88	0.10	0.09	4.07	0.517	0.610
46	23	1.49	1.60	0.96	4.05	0.528	0.607
47	45	2.82	0.31	0.82	3.95	0.539	0.597
48	25	2.07	0.58	1.12	3.77	0.551	0.576
49	30	2.92	1.02	0.23	3.77	0.562	0.576
50	37	2.16	0.83	0.66	3.65	0.573	0.562
51	26	1.20	0.20	2.23	3.63	0.584	0.560
52	0	1.40	0.75	1.48	3.63	0.596	0.560

Table A-26. (continued)

53	46	1.81	0.97	0.77	3.55	0.607	0.550
54	27	1.72	0.77	0.92	3.41	0.618	0.533
55	44	1.46	0.60	1.34	3.40	0.629	0.531
56	5	2.72	0.56	0.11	3.39	0.640	0.530
57	41	1.51	1.07	0.80	3.38	0.652	0.529
58	33	1.37	0.21	1.77	3.35	0.663	0.525
59	1	2.86	0.34	0.14	3.34	0.674	0.524
60	58	2.20	0.86	0.22	3.28	0.685	0.516
61	49	1.13	1.52	0.58	3.23	0.697	0.509
62	0	1.03	0.22	1.98	3.23	0.708	0.509
63	57	1.87	0.85	0.45	3.17	0.719	0.501
64	17	2.76	0.09	0.32	3.17	0.730	0.501
65	84	1.77	0.51	0.88	3.16	0.742	0.500
66	40	0.83	2.26	0.02	3.11	0.753	0.493
67	74	1.75	0.64	0.70	3.09	0.764	0.490
68	32	0.50	0.68	1.85	3.03	0.775	0.481
69	18	0.58	1.47	0.96	3.01	0.787	0.479
70	60	0.62	0.03	2.31	2.96	0.798	0.471
71	85	1.56	0.23	1.12	2.91	0.809	0.464
72	38	1.17	1.06	0.56	2.79	0.820	0.446
73	88	1.49	0.87	0.29	2.65	0.831	0.423
74	36	1.73	0.45	0.47	2.65	0.843	0.423
75	79	0.84	0.67	1.10	2.61	0.854	0.417
76	61	0.71	1.20	0.67	2.58	0.865	0.412
77	4	0.60	0.78	1.15	2.53	0.876	0.403
78	35	1.03	1.11	0.37	2.51	0.888	0.400
79	19	0.55	0.88	1.06	2.49	0.899	0.396
80	67	2.38	0.07	0.01	2.46	0.910	0.391
81	21	1.22	0.62	0.56	2.40	0.921	0.380
82	59	1.58	0.04	0.68	2.30	0.933	0.362
83	31	1.46	0.70	0.01	2.17	0.944	0.336
84	73	1.52	0.05	0.56	2.13	0.955	0.328
85	22	0.54	0.81	0.76	2.11	0.966	0.324
86	62	0.82	0.16	0.95	1.93	0.978	0.286
87	10	0.40	0.43	0.67	1.50	0.989	0.176
88	29	0.95	0.31	0.14	1.40	1.000	0.146

number of values = 88
arithmetic average = 4.34log average = 0.605

std. deviation = 1.68log std. dev. = 0.173
coeff of variation = 0.39log cof. var. = 0.287
arithmetic skew = 0.541log skew = -0.221

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	0.44	1.59	1.49
95.00	1.053	1.58	2.09	2.04
90.00	1.111	2.19	2.41	2.39
80.00	1.250	2.93	2.88	2.89
50.00	2.000	4.34	4.02	4.08
20.00	5.000	5.76	5.63	5.65
10.00	10.000	6.50	6.71	6.64
5.00	20.000	7.10	7.76	7.56
1.00	100.000	8.25	10.18	9.54

Table A-27. Extended fire season (June - September) historical precipitation at Kalispell, MT.

Weight: 1.00 Station: 4558, KALISPELL WSO AP

Start Yr. 0 End Yr. 88

Year (Wt.)	June (1.00)	July (1.00)	August (1.00)	September (1.00)	INDEX TOTAL
0	1.40	0.75	1.48	3.02	6.65
1	2.86	0.34	0.14	1.81	5.15
2	1.51	2.65	0.95	0.76	5.87
3	1.61	1.70	0.78	1.49	5.58
4	0.60	0.78	1.15	0.40	2.93
5	2.72	0.56	0.11	1.21	4.60
6	1.03	0.22	1.98	0.23	3.46
7	3.01	1.14	2.54	2.12	8.81
8	2.48	1.44	0.88	2.01	6.81
9	3.05	3.07	0.11	1.21	7.44
10	0.40	0.43	0.67	2.31	3.81
11	3.83	0.78	1.44	2.75	8.80
12	2.59	1.56	1.03	0.68	5.86
13	3.21	0.38	0.61	0.31	4.51
14	2.51	0.69	1.31	1.21	5.72
15	2.09	2.74	0.22	2.04	7.09
16	3.91	1.76	1.96	1.63	9.26
17	2.76	0.09	0.32	0.83	4.00
18	0.58	1.47	0.96	1.59	4.60
19	0.55	0.88	1.06	0.50	2.99
20	0.95	0.98	2.61	0.70	5.24
21	1.22	0.62	0.56	0.79	3.19
22	0.54	0.81	0.76	0.52	2.63
23	1.49	1.60	0.96	0.23	4.28
24	3.24	0.97	0.74	0.90	5.85
25	2.07	0.58	1.12	2.43	6.20
26	1.20	0.20	2.23	2.14	5.77
27	1.72	0.77	0.92	2.76	6.17
28	2.51	1.49	1.14	0.04	5.18
29	0.95	0.31	0.14	0.51	1.91
30	2.52	1.02	0.23	2.67	6.44
31	1.46	0.70	0.01	2.89	5.06
32	0.50	0.68	1.85	0.15	3.18
33	1.37	0.21	1.77	1.04	4.39
34	*****	0.27	0.07	0.71	*****
35	1.03	1.11	0.37	0.14	2.65
36	1.73	0.45	0.47	1.04	3.69
37	2.16	0.83	0.66	0.91	4.56
38	1.17	1.06	0.56	1.14	3.93
39	3.80	0.38	0.21	0.96	5.35
40	0.83	2.26	0.02	1.69	4.80
41	1.51	1.07	0.80	2.04	5.42
42	4.13	2.72	0.90	0.31	8.06
43	3.33	0.45	0.42	0.23	4.43
44	1.46	0.60	1.34	0.75	4.15
45	2.82	0.31	0.82	1.57	5.52
46	1.81	0.97	0.77	1.30	4.85
47	4.56	0.47	3.28	0.99	9.30
48	2.76	3.15	2.33	0.10	8.34
49	1.13	1.52	0.58	0.95	4.18
50	3.56	2.74	1.24	0.54	8.08
51	1.81	1.08	2.63	1.88	7.40
52	3.26	0.72	1.02	0.12	5.12
53	2.93	0.02	1.98	0.44	5.37
54	1.98	2.09	3.04	0.81	7.92
55	3.06	1.32	0.00	1.55	5.93
56	2.92	2.32	1.93	0.92	8.09
57	1.87	0.85	0.45	0.20	3.37

Table A-27. (continued)

58	2.20	0.86	0.22	1.84	5.12
59	1.58	0.04	0.68	3.84	6.14
60	0.62	0.03	2.31	0.33	3.29
61	0.71	1.20	0.67	2.08	4.66
62	0.82	0.16	0.95	0.42	2.35
63	3.94	0.95	0.81	1.26	6.96
64	3.56	1.69	1.77	1.87	8.89
65	2.73	0.85	3.47	1.17	8.22
66	4.72	0.37	1.05	0.29	6.43
67	2.38	0.07	0.01	0.33	2.79
68	2.16	0.46	3.10	3.33	9.05
69	3.88	0.10	0.09	1.44	5.51
70	2.58	1.59	0.34	0.90	5.41
71	3.59	0.93	1.47	0.46	6.45
72	1.69	1.51	1.03	0.76	4.99
73	1.52	0.05	0.56	0.71	2.84
74	1.75	0.64	0.70	1.18	4.27
75	1.96	0.98	2.79	0.58	6.31
76	1.69	1.64	3.78	0.36	7.47
77	0.43	2.57	1.13	2.18	6.31
78	0.91	1.50	2.64	0.80	5.85
79	0.84	0.67	1.10	0.39	3.00
80	2.96	0.81	1.60	0.74	6.11
81	3.62	0.72	1.32	0.48	6.14
82	4.05	1.59	0.82	1.92	8.38
83	3.09	2.06	0.73	1.31	7.19
84	1.77	0.51	0.88	1.88	5.04
85	1.56	0.23	1.12	3.97	6.88
86	2.17	1.42	0.68	2.78	7.05
87	1.20	3.98	1.35	0.60	7.13
88	1.49	0.87	0.29	2.10	4.75
				AVERAGE	5.58
				MAXIMUM	9.30
				MINIMUM	1.91

****

number of values = 88
arithmetic average = 5.58log average = 0.722
std. deviation = 1.80log std. dev. = 0.153
coeff of variation = 0.32log cof. var. = 0.211
arithmetic skew = 0.167log skew = -0.576

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	1.38	2.33	2.01
95.00	1.053	2.61	2.96	2.81
90.00	1.111	3.27	3.36	3.31
80.00	1.250	4.06	3.92	3.98
50.00	2.000	5.58	5.27	5.45
20.00	5.000	7.10	7.08	7.12
10.00	10.000	7.89	8.27	8.05
5.00	20.000	8.55	9.39	8.82
1.00	100.000	9.77	11.93	10.27

Table A-28. Extended fire season (June - September) historical precipitation at Kalispell, MT ranked in declining amount.

Gage No. Station : 4558,KALISPELL WSO AP

Ranks #	WY #	Jun inches	Jul inches	Aug inches	Sep inches	Total inches	Weibull plotpos	Value log10
1	47	4.56	0.47	3.28	0.99	9.30	0.022	0.968
2	16	3.91	1.76	1.96	1.63	9.26	0.034	0.967
3	68	2.16	0.46	3.10	3.33	9.05	0.045	0.957
4	64	3.56	1.69	1.77	1.87	8.89	0.056	0.949
5	7	3.01	1.14	2.54	2.12	8.81	0.067	0.945
6	11	3.83	0.78	1.44	2.75	8.80	0.079	0.944
7	82	4.05	1.59	0.82	1.92	8.38	0.090	0.923
8	48	2.76	3.15	2.33	0.10	8.34	0.101	0.921
9	65	2.73	0.85	3.47	1.17	8.22	0.112	0.915
10	56	2.92	2.32	1.93	0.92	8.09	0.124	0.908
11	50	3.56	2.74	1.24	0.54	8.08	0.135	0.907
12	42	4.13	2.72	0.90	0.31	8.06	0.146	0.906
13	54	1.98	2.09	3.04	0.81	7.92	0.157	0.899
14	70	1.69	1.64	3.78	0.36	7.47	0.169	0.873
15	9	3.05	3.07	0.11	1.21	7.44	0.180	0.872
16	51	1.81	1.08	2.63	1.88	7.40	0.191	0.869
17	83	3.09	2.06	0.73	1.31	7.19	0.202	0.857
18	87	1.20	3.98	1.35	0.60	7.13	0.213	0.853
19	15	2.09	2.74	0.22	2.04	7.09	0.225	0.851
20	86	2.17	1.42	0.68	2.78	7.05	0.236	0.848
21	63	3.94	0.95	0.81	1.26	6.96	0.247	0.843
22	85	1.56	0.23	1.12	3.97	6.88	0.258	0.838
23	8	2.48	1.44	0.88	2.01	6.81	0.270	0.833
24	0	1.40	0.75	1.48	3.02	6.65	0.281	0.823
25	71	3.59	0.93	1.47	0.46	6.45	0.292	0.810
26	30	2.52	1.02	0.23	2.67	6.44	0.303	0.809
27	66	4.72	0.37	1.05	0.29	6.43	0.315	0.808
28	75	1.96	0.98	2.79	0.58	6.31	0.326	0.800
29	77	0.43	2.57	1.13	2.18	6.31	0.337	0.800
30	25	2.07	0.58	1.12	2.43	6.20	0.348	0.792
31	27	1.72	0.77	0.92	2.76	6.17	0.360	0.790
32	81	3.62	0.72	1.32	0.48	6.14	0.371	0.788
33	59	1.58	0.04	0.68	3.84	6.14	0.382	0.788
34	80	2.96	0.81	1.60	0.74	6.11	0.393	0.786
35	55	3.06	1.32	0.00	1.55	5.93	0.404	0.773
36	2	1.51	2.65	0.95	0.76	5.87	0.416	0.769
37	12	2.59	1.56	1.03	0.68	5.86	0.427	0.768
38	78	0.91	1.50	2.64	0.80	5.85	0.438	0.767
39	24	3.24	0.97	0.74	0.90	5.85	0.449	0.767
40	26	1.20	0.20	2.23	2.14	5.77	0.461	0.761
41	14	2.51	0.69	1.31	1.21	5.72	0.472	0.757
42	3	1.61	1.70	0.78	1.49	5.58	0.483	0.747
43	45	2.82	0.31	0.82	1.57	5.52	0.494	0.742
44	69	3.88	0.10	0.09	1.44	5.51	0.506	0.741
45	41	1.51	1.07	0.80	2.04	5.42	0.517	0.734
46	70	2.58	1.59	0.34	0.90	5.41	0.528	0.733
47	53	2.93	0.02	1.98	0.44	5.37	0.539	0.730
48	39	3.80	0.38	0.21	0.96	5.35	0.551	0.728
49	20	0.95	0.98	2.61	0.70	5.24	0.562	0.719
50	28	2.51	1.49	1.14	0.04	5.18	0.573	0.714
51	1	2.86	0.34	0.14	1.81	5.15	0.584	0.712
52	58	2.20	0.86	0.22	1.84	5.12	0.596	0.709

Table A-28. (continued)

53	52	3.26	0.72	1.02	0.12	5.12	0.607	0.709
54	31	1.46	0.70	0.01	2.89	5.06	0.618	0.704
55	84	1.77	0.51	0.88	1.88	5.04	0.629	0.702
56	72	1.69	1.51	1.03	0.76	4.99	0.640	0.698
57	46	1.81	0.97	0.77	1.30	4.85	0.652	0.686
58	40	0.83	2.26	0.02	1.69	4.80	0.663	0.681
59	88	1.49	0.87	0.29	2.10	4.75	0.674	0.677
60	61	0.71	1.20	0.67	2.08	4.66	0.685	0.668
61	18	0.58	1.47	0.96	1.59	4.60	0.697	0.663
62	5	2.72	0.56	0.11	1.21	4.60	0.708	0.663
63	37	2.16	0.83	0.66	0.91	4.56	0.719	0.659
64	13	3.21	0.38	0.61	0.31	4.51	0.730	0.654
65	43	3.33	0.45	0.42	0.23	4.43	0.742	0.646
66	33	1.37	0.21	1.77	1.04	4.39	0.753	0.642
67	23	1.49	1.60	0.96	0.23	4.28	0.764	0.631
68	74	1.75	0.64	0.70	1.18	4.27	0.775	0.630
69	49	1.13	1.52	0.58	0.95	4.18	0.787	0.621
70	44	1.46	0.60	1.34	0.75	4.15	0.798	0.618
71	17	2.76	0.09	0.32	0.83	4.00	0.809	0.602
72	38	1.17	1.06	0.56	1.14	3.93	0.820	0.594
73	10	0.40	0.43	0.67	2.31	3.81	0.831	0.581
74	36	1.73	0.45	0.47	1.04	3.69	0.843	0.567
75	6	1.03	0.22	1.98	0.23	3.46	0.854	0.539
76	57	1.87	0.85	0.45	0.20	3.37	0.865	0.528
77	60	0.62	0.03	2.31	0.33	3.29	0.876	0.517
78	21	1.22	0.62	0.56	0.79	3.19	0.888	0.504
79	32	0.50	0.68	1.85	0.15	3.18	0.899	0.502
80	79	0.84	0.67	1.10	0.39	3.00	0.910	0.477
81	19	0.55	0.88	1.06	0.50	2.99	0.921	0.476
82	4	0.60	0.78	1.15	0.40	2.93	0.933	0.467
83	73	1.52	0.05	0.56	0.71	2.84	0.944	0.453
84	67	2.38	0.07	0.01	0.33	2.79	0.955	0.446
85	35	1.03	1.11	0.37	0.14	2.65	0.966	0.423
86	22	0.54	0.81	0.76	0.52	2.63	0.978	0.420
87	62	0.82	0.16	0.95	0.42	2.35	0.989	0.371
88	29	0.95	0.31	0.14	0.51	1.91	1.000	0.281

number of values = 88
arithmetic average = 5.58log average = 0.722

std. deviation = 1.80log std. dev. = 0.153
coeff of variation = 0.32log cof. var. = 0.211
arithmetic skew = 0.167log skew = -0.576

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	1.38	2.33	2.01
95.00	1.053	2.61	2.96	2.81
90.00	1.111	3.27	3.36	3.31
80.00	1.250	4.06	3.92	3.98
50.00	2.000	5.58	5.27	5.45
20.00	5.000	7.10	7.08	7.12
10.00	10.000	7.89	8.27	8.05
5.00	20.000	8.55	9.39	8.82
1.00	100.000	9.77	11.93	10.27

Table A-29. Kalispell, MT climatological summary.

TAPS Station : KALISPELL WSO AP, 4558
start yr. - 1900 end yr. - 1988

	Temperature						Precipitation			
				2 years in 10 will have				2 yrs in 10 will have		
Month	avg daily max	avg daily min	avg	max temp. >than	min temp. <than	avg no. of grow'n degree days*	avg (in.)	less than (in.)	more than (in.)	average number of days with 0.10 inch or more
January	28.3	13.8	21.0	52	-22	1	1.39	0.84	1.88	4
February	33.9	17.3	25.6	52	-16	2	1.01	0.54	1.42	3
March	42.9	24.1	33.5	63	-5	22	0.95	0.54	1.33	3
April	54.9	32.1	43.5	78	16	141	0.98	0.50	1.40	3
May	64.1	39.5	51.8	85	25	367	1.66	0.86	2.35	5
June	71.0	45.7	58.4	91	32	551	2.15	1.15	3.02	6
July	80.7	49.7	65.2	103	36	781	1.06	0.34	1.65	3
August	78.9	48.1	63.5	95	33	729	1.13	0.35	1.80	3
September	67.4	40.3	53.9	88	23	419	1.22	0.45	1.86	3
October	54.9	32.1	43.5	76	14	150	1.02	0.38	1.58	3
November	39.1	24.7	31.9	59	-3	14	1.37	0.66	1.98	4
December	30.9	18.0	24.4	51	-15	3	1.41	0.75	1.98	4
Yearly :										
Average	53.9	32.1	43.0	----	----	----	---	---	---	---
Extreme	[illegible]	-38	---	104	-26	----	---	---	---	---
Total	---	---	---	----	----	3180	15.35	11.78	18.26	44

*A growing degree day is a unit of heat available for plant growth. It can be calculated by adding the maximum and minumum daily temperatures, dividing the sum by 2, and subtracting the temperature below which growth is minimal for the principal crops in the area (Threshold : 40.0 deg. F)

FROST Station : KALISPELL WSO AP, 4558
start yr. - 1900 end yr. - 1988

	Temperature		
Probability	24F or lower	28F or lower	32F or lower
Last freezing temperature in spring : March-June			
1 year in 10 later than--	May 3	May 20	June 11
2 year in 10 later than--	April 26	May 13	June 4
5 year in 10 later than--	April 12	May 1	May 22
First freezing temperature in fall : August-Nov.			
1 yr in 10 earlier than--	September 24	September 9	September 2
2 yr in 10 earlier than--	October 1	September 17	September 7
5 yr in 10 earlier than--	October 15	October 1	September 17

Table A-30. Historical monthly snow depth and snow water equivalent measurements from Herrig Junction, MT.

Station : 14A16, HERRIG JUNCTION

Unit = inches

year/	January			February			March			April			May			June		
card	date	dep	swe	date	dep	swe	date	dep	swe	date	dep	swe	date	dep	swe	date	dep	swe
77-1				1/21	31	7.4	2/25	41	11.0	3/24	50	15.8	4/25	24	9.0			
78-1				1/19	70	22.0	2/22	67	22.8	3/28	54	25.1	4/27	45	23.4	6/06	0	0.0
79-1				1/30	46	11.4	2/27	74	21.9	3/27	58	22.3	4/27	53	21.4	5/29	0	0.0
80-1				1/29	43	12.0	2/22	53	17.0	3/27	70	21.8	4/29	30	12.7	5/27	0	0.0
81-1				1/27	49	13.7	2/25	62	18.7	3/31	55	18.3	4/28	44	18.0	5/28	0	0.0
82-1				1/26	67	18.5	2/23	75	25.0	3/30	80	33.2	4/27	78	34.4	5/25	32	15.7
83-1				1/27	60	19.1	2/23	69	22.6	3/30	70	25.3	4/26	68	25.3	6/01	0	0.0
84-1				1/26	42	11.2	2/27	53	14.4	3/27	54	18.0	4/26	38	14.7	5/30	2	0.6
85-1				1/29	52	18.2	2/27	69	22.7	3/26	71	24.4	4/24	57	22.6	5/30	0	0.0
86-1				1/28	47	12.1	2/26	60	17.4	3/25	51	17.9	4/29	32	11.8	5/28	0	0.0
87-1				1/27	46	13.2	2/24	57	17.6	3/30	61	21.5	4/28	33	14.4	5/26	0	0.0
88-1				1/26	40	11.3	2/25	50	15.6	3/29	68	20.8	4/26	38	15.4	5/26	0	0.0
89-1				1/24	64	18.2	2/23	64	21.5	3/28	73	26.9	4/25	51	23.0	5/22	10	4.9
FIRST OF MONTH MEASUREMENTS																		
average depth and swe :					51	14.5		61	19.1		63	22.4		45	18.9		4	1.8
years		0	0		13	13		13	13		13	13		13	13		12	12
1961-1985 average :					51	14.8		63	19.6		62	22.7		49	20.2		4	2.0
years		0	0		9	9		9	9		9	9		9	9		8	8

Table A-31. Historical Water Year precipitation at Hungry Horse Dam, MT.

Station : 4328, HUNGRY HORSE DAM
Unit = inches

yr	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep	SUM
48	4.04	3.00	1.49	2.03	2.86	1.98	3.92	2.77	4.38	3.90	1.24	0.55	32.16
49	1.15	2.79	1.79	1.30	3.49	2.16	1.50	2.75	1.07	1.53	0.79	1.95	22.27
50	2.96	2.71	2.53	7.02	2.07	2.82	1.72	0.65	4.02	2.26	1.43	1.19	31.38
51	6.80	1.53	3.41	2.80	2.49	1.60	0.81	3.16	1.93	1.68	2.97	3.79	32.97
52	6.56	1.41	4.67	2.06	0.91	1.12	0.57	2.50	3.83	1.84	0.94	0.49	26.90
53	0.29	0.72	1.45	5.27	2.07	2.23	2.17	2.68	2.50	0.10	1.52	0.97	21.97
54	0.56	2.46	4.50	6.94	2.48	2.33	2.12	1.84	3.40	2.81	5.21	1.19	35.84
55	1.98	2.43	1.81	1.65	3.50	1.69	2.02	2.22	2.37	3.49	0.00	3.69	26.85
56	6.30	6.42	5.94	3.71	3.02	2.03	2.22	1.47	2.56	1.90	3.31	2.69	41.57
57	2.85	1.17	3.44	2.01	3.64	1.75	1.79	1.39	2.93	0.77	0.98	0.28	23.00
58	3.74	1.57	3.13	3.08	4.48	1.20	3.50	1.89	2.89	1.05	0.73	4.47	31.73
59	1.73	6.56	4.89	6.85	2.60	1.61	2.38	3.98	2.84	0.20	2.11	5.48	41.23
60	4.54	7.37	1.03	2.88	1.70	2.58	1.59	5.03	1.78	0.14	3.74	1.10	33.48
61	3.15	5.94	2.22	1.94	5.11	2.80	5.16	3.23	0.53	1.47	1.53	4.02	37.10
62	3.17	3.16	4.94	1.53	1.75	2.98	3.06	3.39	0.95	0.29	2.04	2.15	29.41
63	5.00	4.74	2.40	2.41	3.22	2.94	2.38	1.23	5.77	1.02	0.87	2.42	34.40
64	1.98	2.64	2.31	3.19	0.97	2.74	1.82	3.96	3.86	3.29	2.31	3.48	32.55
65	2.92	4.92	8.21	3.83	3.23	0.36	3.76	1.87	3.77	1.24	4.31	3.52	41.94
66	0.90	3.26	1.72	3.44	1.69	3.19	2.01	2.18	6.49	1.57	2.13	0.65	29.23
67	3.35	5.46	4.30	6.22	1.33	2.12	1.18	1.82	3.35	0.22	0.11	0.97	30.43
68	5.78	2.88	3.37	3.13	3.21	2.85	1.37	3.37	2.91	2.17	3.71	6.57	41.32
69	4.83	3.63	3.75	7.85	0.83	1.17	1.74	2.29	5.26	0.46	0.14	3.05	35.00
70	2.82	1.83	2.24	6.20	3.52	2.92	1.79	2.24	3.72	3.30	0.58	3.56	34.72
71	3.18	3.83	4.51	5.49	1.95	2.38	1.27	3.24	5.26	2.23	1.60	1.76	36.70
72	4.04	2.99	4.10	5.39	4.03	2.51	2.71	2.23	3.69	3.10	2.29	3.00	40.08
73	3.07	1.00	4.89	2.24	1.09	1.04	1.63	2.39	2.85	0.16	1.01	2.63	24.00
74	4.10	10.84	4.97	7.50	3.82	4.23	2.26	2.89	3.16	1.66	1.07	2.41	48.93
75	0.42	4.11	2.81	3.73	3.61	2.71	1.21	2.57	3.38	1.57	4.07	1.10	31.29
76	5.89	3.09	3.81	3.75	3.10	1.50	2.75	2.89	3.66	2.98	4.74	1.36	39.52
77	0.90	2.18	1.93	1.63	1.70	2.20	1.10	2.74	0.68	3.84	3.04	3.81	25.75
78	1.00	3.95	7.16	3.05	1.44	1.27	2.32	4.28	2.44	1.69	4.13	2.34	35.07
79	0.68	2.89	3.01	2.17	4.87	2.68	2.60	3.08	1.51	0.70	1.30	0.68	26.17
80	3.04	0.60	3.87	2.49	2.54	3.20	2.44	4.19	5.48	1.50	3.61	3.19	36.15
81	1.32	2.82	7.11	1.20	3.91	1.05	4.55	6.17	6.83	2.45	0.87	1.72	40.00
82	1.04	2.95	4.06	4.38	4.22	3.49	3.44	2.00	2.40	3.11	1.58	2.61	35.28
83	1.83	4.12	4.00	2.51	1.67	2.31	2.46	0.97	3.78	5.54	0.75	3.56	33.50
84	2.54	6.33	2.33	2.75	1.12	2.51	2.19	4.03	2.18	1.30	0.38	5.73	33.39
85	3.30	5.42	3.54	0.21	2.06	0.73	1.94	2.50	2.85	0.23	2.53	6.91	32.22
86	3.85	2.42	0.93	3.71	4.28	2.31	1.67	3.16	1.60	3.52	0.05	5.92	33.42
87	2.21	4.77	1.13	1.31	1.13	4.51	2.17	1.53	2.32	4.52	2.12	0.42	28.14
88	0.41	1.67	3.20	2.70	1.88	2.73	2.65	4.27	2.49	1.31	0.89	4.88	29.08
all years ave	2.93	3.53	3.49	3.50	2.65	2.26	2.24	2.76	3.16	1.91	1.92	2.74	33.08
yrs	(41)	(41)	(41)	(41)	(41)	(41)	(41)	(41)	(41)	(41)	(41)	(41)	(41)
1961-1985 average :	2.81	3.84	3.90	3.53	2.64	2.32	2.37	2.87	3.47	1.88	2.03	2.93	34.57
yrs	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)

Table A-32. Prefire season (October-May) historical precipitation at Hungry Horse Dam, MT.

Weight: 1.00 Station: 4328, HUNGRY HORSE DAM

Start Yr. 48 End Yr. 88
Weights for months:
October - 1.00
November - 1.00
December - 1.00
January - 1.00
February - 1.00
March - 1.00
April - 1.00
May - 1.00

Year (wt.)	INDEX TOTAL
48	22.09
49	16.93
50	22.48
51	22.60
52	19.80
53	16.98
54	23.23
55	17.30
56	31.11
57	18.04
58	22.59
59	30.60
60	26.72
61	29.55
62	23.98
63	24.32
64	19.61
65	29.10
66	16.39
67	25.78
68	25.96
69	26.09
70	23.56
71	25.85
72	28.00
73	17.35
74	40.63
75	21.17
76	26.76
77	14.38
78	24.47
79	21.96
80	22.37
81	28.13
82	25.58
83	19.87
84	23.80
85	19.70
86	22.33
87	18.76
88	19.51
AVERAGE	23.4
MAXIMUM	40.6
MINIMUM	14.4

number of values = 41
arithmetic average = 23.35 log average = 1.359
std. deviation = 4.93 log std. dev. = 0.089
coeff of variation = 0.21 log coef. var. = 0.065
arithmetic skew = 0.980 log skew = 0.190

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	11.87	14.22	14.63
95.00	1.053	15.23	16.34	16.53
90.00	1.111	17.03	17.60	17.68
80.00	1.250	19.20	19.26	19.23
50.00	2.000	23.35	22.87	22.73
20.00	5.000	27.50	27.17	27.11
10.00	10.000	29.68	29.73	29.84
5.00	20.000	31.47	32.02	32.36
1.00	100.000	34.83	36.80	37.86

Table A-33. Prefire season (October - May) historical precipitation at Hungry Horse Dam, MT ranked in declining amount.

Gage No. Station : 4328,HUNGRY HORSE DAM

for the months October - May

Ranks #	Water Year	Value inches	Weibull plot pos.	Value log10
1	74	40.65	0.024	1.609
2	56	31.11	0.048	1.493
3	59	30.60	0.071	1.486
4	61	29.55	0.095	1.471
5	65	29.10	0.119	1.464
6	81	28.13	0.143	1.449
7	72	28.00	0.167	1.447
8	76	26.78	0.190	1.428
9	60	26.72	0.214	1.427
10	69	26.09	0.238	1.416
11	66	25.96	0.262	1.414
12	71	25.85	0.286	1.412
13	67	25.78	0.310	1.411
14	82	25.58	0.333	1.408
15	78	24.47	0.357	1.389
16	63	24.32	0.381	1.386
17	62	23.98	0.405	1.380
18	84	23.80	0.429	1.377
19	70	23.56	0.452	1.372
20	54	23.23	0.476	1.366
21	51	22.60	0.500	1.354
22	55	22.59	0.524	1.354
23	50	22.48	0.548	1.352
24	80	22.37	0.571	1.350
25	58	22.33	0.595	1.349
26	48	22.09	0.619	1.344
27	79	21.98	0.643	1.342
28	75	21.17	0.667	1.326
29	83	19.87	0.690	1.298
30	52	19.80	0.714	1.297
31	85	19.70	0.738	1.294
32	64	19.61	0.762	1.292
33	88	19.51	0.786	1.290
34	87	18.76	0.810	1.273
35	86	18.39	0.833	1.265
36	57	18.04	0.857	1.256
37	73	17.35	0.881	1.239
38	55	17.30	0.905	1.238
39	49	16.93	0.929	1.229
40	53	16.88	0.952	1.227
41	77	14.38	0.976	1.158

number of values = 41
arithmetic average = 23.35 log average = 1.359

std. deviation = 4.93 log std. dev. = 0.089
coeff of variation = 0.21 log coef. var. = 0.065
arithmetic skew = 0.980 log skew = 0.190

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	11.87	14.22	14.65
95.00	1.053	15.23	16.34	16.53
90.00	1.111	17.03	17.60	17.68
80.00	1.250	19.20	19.26	19.23
50.00	2.000	23.35	22.87	22.73
20.00	5.000	27.50	27.17	27.11
10.00	10.000	29.68	29.73	29.84
5.00	20.000	31.47	32.02	32.36
1.00	100.000	34.83	36.80	37.36

Table A-34. Fire season (June - August) historical precipitation at Hungry Horse Dam, MT.

Weight: 1.00 Station: 4328, HUNGRY HORSE DAM

Start Yr. 48 End Yr. 88

Year (Wt.)	June (1.00)	July (1.00)	August (1.00)	INDEX TOTAL
48	4.38	3.90	1.24	9.52
49	1.07	1.53	0.79	3.39
50	4.02	2.26	1.43	7.71
51	1.93	1.68	2.97	6.58
52	3.83	1.84	0.94	6.61
53	2.50	0.10	1.52	4.12
54	3.40	2.81	5.21	11.42
55	2.37	3.49	0.00	5.86
56	2.56	1.90	3.31	7.77
57	2.93	0.77	0.98	4.68
58	2.89	1.05	0.73	4.67
59	2.84	0.20	2.11	5.15
60	1.78	0.14	3.74	5.66
61	0.53	1.47	1.53	3.53
62	0.95	0.29	2.04	3.28
63	5.77	1.02	0.87	7.66
64	3.86	3.29	2.31	9.46
65	3.77	1.24	4.31	9.32
66	6.49	1.57	2.13	10.19
67	3.35	0.22	0.11	3.68
68	2.91	2.17	3.71	8.79
69	5.26	0.46	0.14	5.86
70	3.72	3.30	0.58	7.60
71	5.26	2.23	1.60	9.09
72	3.69	3.10	2.29	9.08
73	2.85	0.16	1.01	4.02
74	3.16	1.66	1.07	5.89
75	3.38	1.57	4.07	9.02
76	3.66	2.98	4.74	11.38
77	0.68	3.84	3.04	7.56
78	2.44	1.69	4.13	8.26
79	1.51	0.70	1.30	3.51
80	5.48	1.50	3.61	10.59
81	6.83	2.45	0.87	10.15
82	2.40	3.11	1.58	7.09
83	3.78	5.54	0.75	10.07
84	2.18	1.30	0.38	3.86
85	2.85	0.23	2.53	5.61
86	1.60	3.52	0.05	5.17
87	2.32	4.52	2.12	8.96
88	2.49	1.31	0.89	4.69
			AVERAGE	6.99
			MAXIMUM	11.42
			MINIMUM	3.28

****

number of values = 41
arithmetic average = 6.99 log average = 0.815
std. deviation = 2.46 log std. dev. = 0.165
coeff of variation = 0.35 log cof. var. = 0.203
arithmetic skew = 0.078 log skew = -0.349

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	1.26	2.70	2.45
95.00	1.053	2.94	3.50	3.38
90.00	1.111	3.83	4.01	3.97
80.00	1.250	4.91	4.75	4.79
50.00	2.000	6.99	6.54	6.68
20.00	5.000	9.06	9.00	9.04
10.00	10.000	10.14	10.64	10.47
5.00	20.000	11.04	12.22	11.74
1.00	100.000	12.72	15.83	14.35

Table A-35. Fire season (June - August) historical precipitation at Hungry Horse Dam, MT ranked in declining amount.

Gage No. Station : 4328,HUNGRY HORSE DAM

Ranks #	WY #	Jun inches	Jul inches	Aug inches	Total inches	Weibull plotpos	Value log10
1	54	3.40	2.81	5.21	11.42	0.024	1.058
2	76	3.66	2.98	4.74	11.38	0.048	1.056
3	80	5.48	1.50	3.61	10.59	0.071	1.025
4	66	6.49	1.57	2.13	10.19	0.095	1.008
5	81	6.83	2.45	0.87	10.15	0.119	1.006
6	83	3.78	5.54	0.75	10.07	0.143	1.003
7	48	4.38	3.90	1.24	9.52	0.167	0.979
8	64	3.86	3.29	2.31	9.46	0.190	0.976
9	65	3.77	1.24	4.31	9.32	0.214	0.969
10	71	5.26	2.23	1.60	9.09	0.238	0.959
11	72	3.69	3.10	2.29	9.08	0.262	0.958
12	75	3.38	1.57	4.07	9.02	0.286	0.955
13	87	2.32	4.52	2.12	8.96	0.310	0.952
14	68	2.91	2.17	3.71	8.79	0.333	0.944
15	78	2.44	1.69	4.13	8.26	0.357	0.917
16	56	2.56	1.90	3.31	7.77	0.381	0.890
17	50	4.02	2.26	1.43	7.71	0.405	0.887
18	63	5.77	1.02	0.87	7.66	0.429	0.884
19	70	3.72	3.30	0.58	7.60	0.452	0.881
20	77	0.68	3.84	3.04	7.56	0.476	0.879
21	82	2.40	3.11	1.58	7.09	0.500	0.851
22	52	3.83	1.84	0.94	6.61	0.524	0.820
23	51	1.93	1.68	2.97	6.58	0.548	0.818
24	74	3.16	1.66	1.07	5.89	0.571	0.770
25	55	2.37	3.49	0.00	5.86	0.595	0.768
26	69	5.26	0.46	0.14	5.86	0.619	0.768
27	60	1.78	0.14	3.74	5.66	0.643	0.753
28	85	2.85	0.23	2.53	5.61	0.667	0.749
29	86	1.60	3.52	0.05	5.17	0.690	0.713
30	59	2.84	0.20	2.11	5.15	0.714	0.712
31	88	2.49	1.31	0.89	4.69	0.738	0.671
32	57	2.93	0.77	0.98	4.68	0.762	0.670
33	58	2.89	1.05	0.73	4.67	0.786	0.669
34	53	2.50	0.10	1.52	4.12	0.810	0.615
35	73	2.85	0.16	1.01	4.02	0.833	0.604
36	84	2.18	1.30	0.38	3.86	0.857	0.587
37	67	3.35	0.22	0.11	3.68	0.881	0.566
38	61	0.53	1.47	1.53	3.53	0.905	0.548
39	79	1.51	0.70	1.30	3.51	0.929	0.545
40	49	1.07	1.53	0.79	3.39	0.952	0.530
41	62	0.95	0.29	2.04	3.28	0.976	0.516

number of values = 41
arithmetic average = 6.99log average = 0.815

std. deviation = 2.46log std. dev. = 0.165
coeff of variation = 0.35log cof. var. = 0.203
arithmetic skew = 0.078log skew = -0.349

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	1.26	2.70	2.45
95.00	1.053	2.94	3.50	3.38
90.00	1.111	3.83	4.01	3.97
80.00	1.250	4.91	4.75	4.79
50.00	2.000	6.99	6.54	6.68
20.00	5.000	9.06	9.00	9.04
10.00	10.000	10.14	10.64	10.47
5.00	20.000	11.04	12.22	11.74
1.00	100.000	12.72	15.83	14.35

Table A-36. Extended fire season (June-September) historical precipitation at Hungry Horse Dam, MT.

Weight: 1.00 Station: 4328, HUNGRY HORSE DAM

Start Yr. 48 End Yr. 88

Year (wt.)	June (1.00)	July (1.00)	August (1.00)	September (1.00)	INDEX TOTAL
48	4.38	3.90	1.24	0.55	10.07
49	1.07	1.53	0.79	1.95	5.34
50	4.02	2.26	1.43	1.19	8.90
51	1.93	1.68	2.97	3.79	10.37
52	3.83	1.84	0.94	0.49	7.10
53	2.56	0.10	1.52	0.97	5.09
54	3.40	2.61	5.21	1.19	12.61
55	2.37	3.49	0.00	3.69	9.55
56	2.56	1.90	3.31	2.69	10.46
57	2.93	0.77	0.98	0.28	4.96
58	2.89	1.05	0.73	4.47	9.14
59	2.84	0.20	2.11	5.48	10.63
60	1.78	0.14	3.74	1.10	6.76
61	0.53	1.47	1.53	4.02	7.55
62	0.95	0.29	2.04	2.15	5.43
63	5.77	1.02	0.87	2.42	10.08
64	3.86	3.29	2.31	3.48	12.94
65	3.77	1.24	4.31	3.52	12.84
66	6.49	1.57	2.13	0.65	10.84
67	3.35	0.22	0.11	0.97	4.65
68	2.91	2.17	3.71	6.57	15.36
69	5.26	0.46	0.14	3.05	8.91
70	3.72	3.30	0.58	3.56	11.16
71	5.26	2.23	1.60	1.76	10.85
72	3.69	3.10	2.29	3.00	12.08
73	2.85	0.16	1.01	2.63	6.65
74	3.16	1.66	1.07	2.41	8.30
75	3.38	1.57	4.07	1.10	10.12
76	3.66	2.98	4.74	1.36	12.74
77	0.68	3.84	3.04	3.81	11.37
78	2.44	1.69	4.13	2.34	10.60
79	1.51	0.70	1.30	0.68	4.19
80	5.48	1.50	3.61	3.19	13.78
81	6.83	2.45	0.87	1.72	11.87
82	2.40	3.11	1.58	2.61	9.70
83	3.78	5.54	0.75	3.56	13.63
84	2.16	1.30	0.38	5.73	9.59
85	2.83	0.23	2.53	6.91	12.52
86	1.60	3.52	0.05	5.92	11.09
87	2.32	4.52	2.12	0.42	9.38
88	2.49	1.31	0.89	4.88	9.57

AVERAGE	9.73
MAXIMUM	15.36
MINIMUM	4.19

****

number of values = 41

arithmetic average = 9.73 log average = 0.966

std. deviation = 2.75 log std. dev. = 0.141

coeff of variation = 0.28 log coef. var. = 0.146

arithmetic skew = -0.354 log skew = -0.951

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	3.32	4.36	3.51
95.00	1.053	5.20	5.44	5.06
90.00	1.111	6.20	6.12	6.00
80.00	1.250	7.41	7.06	7.24
50.00	2.000	9.73	9.28	9.77
20.00	5.000	12.04	12.21	12.25
10.00	10.000	13.25	14.06	13.44
5.00	20.000	14.25	15.85	14.33
1.00	100.000	16.13	19.78	15.74

Table A-37. Extended fire season (June-September) historical precipitation at Hungry Horse Dam, MT ranked in declining amount.

Gage No. Station : 4328,HUNGRY HORSE DAM

Ranks #	WY #	Jun inches	Jul inches	Aug inches	Sep inches	Total inches	Weibull plotpos	Value log10
1	68	2.91	2.17	3.71	6.57	15.36	0.024	1.186
2	80	5.48	1.50	3.61	3.19	13.78	0.048	1.139
3	83	3.78	5.54	0.75	3.56	13.63	0.071	1.134
4	64	3.86	3.29	2.31	3.48	12.94	0.095	1.112
5	65	3.77	1.24	4.31	3.52	12.84	0.119	1.109
6	76	3.66	2.98	4.74	1.36	12.74	0.143	1.105
7	54	3.40	2.81	5.21	1.19	12.61	0.167	1.101
8	85	2.85	0.23	2.53	6.91	12.52	0.190	1.098
9	72	3.69	3.10	2.29	3.00	12.08	0.214	1.082
10	81	6.83	2.45	0.87	1.72	11.87	0.238	1.074
11	77	0.68	3.84	3.04	3.81	11.37	0.262	1.056
12	70	3.72	3.30	0.58	3.56	11.16	0.286	1.048
13	86	1.60	3.52	0.05	5.92	11.09	0.310	1.045
14	71	5.26	2.23	1.60	1.76	10.85	0.333	1.035
15	66	6.49	1.57	2.13	0.65	10.84	0.357	1.035
16	59	2.84	0.20	2.11	5.48	10.63	0.381	1.027
17	78	2.44	1.69	4.13	2.34	10.60	0.405	1.025
18	56	2.56	1.90	3.31	2.69	10.46	0.429	1.020
19	51	1.93	1.68	2.97	3.79	10.37	0.452	1.016
20	75	3.38	1.57	4.07	1.10	10.12	0.476	1.005
21	63	5.77	1.02	0.87	2.42	10.08	0.500	1.003
22	48	4.38	3.90	1.24	0.55	10.07	0.524	1.003
23	82	2.40	3.11	1.58	2.61	9.70	0.548	0.987
24	84	2.18	1.30	0.38	5.73	9.59	0.571	0.982
25	88	2.49	1.31	0.89	4.88	9.57	0.595	0.981
26	55	2.37	3.49	0.00	3.69	9.55	0.619	0.980
27	87	2.32	4.52	2.12	0.42	9.38	0.643	0.972
28	58	2.89	1.05	0.73	4.47	9.14	0.667	0.961
29	69	5.26	0.46	0.14	3.05	8.91	0.690	0.950
30	50	4.02	2.26	1.43	1.19	8.90	0.714	0.949
31	74	3.16	1.66	1.07	2.41	8.30	0.738	0.919
32	61	0.53	1.47	1.53	4.02	7.55	0.762	0.878
33	52	3.83	1.84	0.94	0.49	7.10	0.786	0.851
34	60	1.78	0.14	3.74	1.10	6.76	0.810	0.830
35	73	2.85	0.16	1.01	2.63	6.65	0.833	0.823
36	62	0.95	0.29	2.04	2.15	5.43	0.857	0.735
37	49	1.07	1.53	0.79	1.95	5.34	0.881	0.728
38	53	2.50	0.10	1.52	0.97	5.09	0.905	0.707
39	57	2.93	0.77	0.98	0.28	4.96	0.929	0.695
40	67	3.35	0.22	0.11	0.97	4.65	0.952	0.667
41	79	1.51	0.70	1.30	0.68	4.19	0.976	0.622

number of values = 41
arithmetic average = 9.73log average = 0.968

std. deviation = 2.75log std. dev. = 0.141
coeff of variation = 0.28log cof. var. = 0.146
arithmetic skew = -0.354log skew = -0.951

Exceed % Prob	Return Period	Normal Probability	Log Normal Probability	LP3 Probability
99.00	1.010	3.32	4.36	3.51
95.00	1.053	5.20	5.44	5.06
90.00	1.111	6.20	6.12	6.00
80.00	1.250	7.41	7.06	7.24
50.00	2.000	9.73	9.28	9.77
20.00	5.000	12.04	12.21	12.25
10.00	10.000	13.25	14.08	13.44
5.00	20.000	14.25	15.85	14.33
1.00	100.000	16.13	19.78	15.74

Table A-38. Hungry Horse Dam, MT climatological summary.

TAPS Station : HUNGRY HORSE DAM, 4328
start yr. - 1948 end yr. - 1988

Month	Temperature: avg daily max	avg daily min	avg	2 years in 10 will have: max temp. >than	min temp. <than	avg no. of grow'n degree days*	Precipitation: avg (in.)	2 yrs in 10 will have: less than (in.)	more than (in.)	average number of days with 0.10 inch or more
January	28.2	14.1	21.1	51	-21	2	3.62	1.81	5.20	9
February	35.0	18.9	27.0	53	-16	3	2.58	1.54	3.51	7
March	41.9	22.7	32.3	61	-10	14	2.25	1.39	3.02	7
April	52.1	31.2	41.6	75	15	103	2.18	1.41	2.88	6
May	63.6	39.2	51.4	86	26	387	2.77	1.77	3.68	7
June	71.3	45.7	58.5	91	33	631	3.25	1.82	4.52	8
July	80.0	49.9	65.0	96	38	803	1.76	0.59	2.72	4
August	78.9	49.0	64.0	95	38	778	1.97	0.71	3.12	5
September	66.2	40.7	53.4	87	27	461	2.36	1.01	3.51	7
October	52.2	33.0	42.6	73	18	124	2.90	1.22	4.33	6
November	37.9	25.3	31.6	58	1	13	3.54	1.82	5.04	8
December	31.5	19.2	25.3	52	-12	3	3.53	2.06	4.84	10
Yearly :										
Average	53.2	32.4	42.8	----	----	----	---	---	---	---
Extreme	102	-40	---	98	-25	----	---	---	---	---
Total	---	---	---	----	----	3321	32.72	20.13	39.03	84

*A growing degree day is a unit of heat available for plant growth. It can be calculated by adding the maximum and minumum daily temperatures, dividing the sum by 2, and subtracting the temperature below which growth is minimal for the principal crops in the area (Threshold : 40.0 deg. F)

FROST Station : HUNGRY HORSE DAM, 4328
start yr. - 1948 end yr. - 1988

Probability	Temperature: 24F or lower	28F or lower	32F or lower
Last freezing temperature in spring : March-June			
1 year in 10 later than--	April 27	May 14	June 6
2 year in 10 later than--	April 21	May 7	May 31
5 year in 10 later than--	April 10	April 25	May 19
First freezing temperature in fall : August-Nov.			
1 yr in 10 earlier than--	October 8	September 16	September 3
2 yr in 10 earlier than--	October 14	September 24	September 13
5 yr in 10 earlier than--	October 27	October 8	September 21

Appendix B - Fire Danger

Introduction

Fire danger is measured using several indices with input from the daily weather measurements taken at the different NFDRS stations (Deeming and others 1977). The NFDRS stations used to help describe the climatology of the North Fork of the Flathead River will be used again for comparison of the Fire Danger indices. In addition two other stations; Spotted Bear Lookout and Spotted Bear Ranger Station (Flathead National Forest) from the northwest corner of the Bob Marshall Wilderness complex will be include to gain a Fire Danger perspective extending even further south as well as provide a high elevation station for comparison with fire danger in the lower elevations. The indices Energy Release Component (ERC), Burning Index (BI), and Thousand Hour Fuel Moisture will be used.

The Energy Release Component is an index that calculates the estimated potential available energy released per square foot during the flaming combustion zone using standardized fuel models. An open ended scale is used to increase index sensitivity. Model characteristic surface area-to-volume ratio and weighted fuel moisture of the fuel bed are calculated using fuel class weighting factors based on loading (Bradshaw and others 1983). Day to day variations of the ERC are caused by changes in the moisture content of the various fuel size classes, including the larger fuel particles (Deeming and others 1977). The ERC for fuel model G is considered to be a good indicator of long term drying and is used as prescription guidelines in most manuals for prescribed natural fire prescriptions. Many wildland fire suppression organizations also use the ERC as their basic index gaging the fire danger of their current fire season. This index is usually discussed in terms of a percentile level, as well as an actual ERC number. The percentile levels are calculated from frequency distributions of historical ERC levels. For comparison purposes the percentile levels are calculated in this report for the 1973-1987 seasons. This would have been data available at the time of the Red Bench Fire. NFDRS records prior to 1973 were not used because the weather records are incomplete. At some stations this information has been artificially generated and can produce misleading and inaccurate results (Burgan, personal communication 1988). Through experience it has been learned that an ERC of the 80th percentile or greater will require more management for fire suppression than for fires below that ERC level. The 80th and 90th percentile levels are common guidelines within prescribed natural fire prescriptions. These two levels, along with the 97th and 100th percentiles are presented for each station. Comparisons are made with an average 3-day running mean, to smooth out irregularities, for the years 1973-1987 and with previous recent seasons classified as severe in the Northern Rocky Mountains; 1967, 1973, 1985, as well as the 1988 season.

Finklin (1985) found that severe fire danger seasons which he classified as an "Early" type typically reached the 70th percentile level by June 20th and the 80th percentile by July 1st. "Late" type seasons reached the 70th percentile by July 25th and the 80th between August 1st and 10th. The downward curves for all three severe season types he found to be similar after September 1-10. Finklin described the 1967 season, which had a major impact within Glacier National Park and Northern Idaho (Anderson 1968; Fischer 1969) as "Late" on both side of the Continental Divide. At the Polebridge Ranger Station however, in 1967 the ERC index was above the 80th percentile level by the end of June making that season a "Main" type severe fire season rather than

the "Late" as Finklin described for the region. The 1973 seasons Finklin determined to be a "Main" type on the west side of the divide and not severe on the east side based on ERC. Using Finklin's classifications for the last two seasons, and for only low elevation NFDRS stations, placed 1985 on both sides of the divide as an early season, and 1988 as both "Main" and "Late" types west of the divide. Fire danger during the 1988 season was more severe earlier during the fire season at locations along the Northern Rocky Mountains in central and southern Montana causing a "Main" type season, further north in Glacier National Park and the Flathead National Forest Fire Danger indices indicate a "Late" season. Examining only high elevation NFDRS fire lookout stations (Spotted Bear Lookout, Flathead National Forest and further south the Silver King Lookout, Helena National Forest), all four severe fire danger years may be classified as late "Main" type combined with an early "Late" type seasons (Bushey 1990).

The Burning Index is an index related to the contribution of fire behavior to the effort of containing a fire (Deeming and others 1977). The BI is based on flame length; and the BI, flame length and fireline intensity are all interrelated. In 1978 the BI was scaled to be ten times the calculated flame length. Percentile levels for the 1973-1987 historical record are presented with the 3-day running mean for the average BI for those seasons. Comparisons of BI for the severe fire seasons of 1967, 1973, 1985 and 1988 are made. Within the USDI National Park Service the BI index has historically been used as a day-to-day gage of the wildfire season severity.

Thousand Hour Fuel Moisture is an index of fuel moisture for large fuel particles, commonly called 1,000-Hour Timelag Fuel. These particles are described as 3-8" (7.62-20.32 cm) in diameter either on or near the forest floor, or no more than 4" (10.16 cm) below the surface. A factor of 1,000 hours is used as a guideline for these fuels to lose an approximate 66% of their weight in moisture. The Thousand Hour Fuel Moisture model is calculated each 24 hours using the maximum and minimum temperatures and relative humidities, and the precipitation (if any) duration. The Thousand Hour Fuel Moisture is calculated from a running 7-day average of the daily factors and the Thousand Hour Fuel Moisture at the beginning of the 7 day period. This index is considered to be a good indicator of the severity of a medium drought event (4-6 months duration) (Bradshaw and others 1983). A season minimum moisture level for Thousand Hour Timelag Fuel of 9% within Fuel Model G in the Northern Rocky Mountains is indicative of this type of drought event. It is highly unusual for fuel particles of this large size to drop to such low moisture levels. In the Model G forest types around Glacier National Park it is exceptional to have fuel of this size drop down to season minimal values of 12-13%. For ease of comparison the average 3-day running mean Thousand Hour Fuel Moisture was calculated using the same years as used with both the ERC and BI indices 1973-1987. Comparison of the 1988 3-day running mean is made with the 1967, 1973, and 1985 seasons.

Fire danger varies from station to station over a geographic area, and fire danger indices such as ERC and BI are not necessarily comparable between stations; an ERC of 52 will not mean the same at Spotted Bear Ranger Station as the same index number at Polebridge Ranger Station. The Thousand Hour Fuel Moisture is a comparable index over geographic areas and a good indicator of short term drought. Differences of between 2 and 5% in Thousand Hour Fuel Moisture can be quite significant in the determination between a "normal" or "severe" fire danger season. Comparing the indices trends from the differing stations, and especially when they pass significant percentile or moisture levels or the length of time at or above particular index levels can provide a

good indication of how fire danger varies over a large area. The 1967 season is a good example. It can be seen from the following fire danger index examples that although that season was rated as severe across the Northern Rocky Mountains, the season was gaged much more severe with increasing latitude. The opposite becomes apparent for the 1988 fire season with a trend of increasing severity with decreasing latitude (Bushey 1990). And at all of the stations examined the 1985 season was rapidly progressing into an early season with the potential for record, or near record fire danger with numerous and increasing numbers of ignitions in progress before the season ending rains arrived about August 1st. The 1973 season would eventually be noted as a season of considerable potential with very serious burning conditions and low Thousand Hour Fuel Moisture content, but generally lacked ignitions over most of the Northern Rocky Mountains. Interestingly, all four severe Fire Danger seasons east of the Continental Divide developed in to seasons with strong fire danger potential under the influence of the Continental Type weather patterns. A greater affinity, or fire danger similarity, at the east side stations is apparent between the west side stations of lower latitudes than to the more moist west side stations further north (Bushey 1990).

NFDRS Fire Danger and Comparisons with 1988

POLEBRIDGE RANGER STATION, GLACIER NATIONAL PARK, POLEBRIDGE, MONTANA

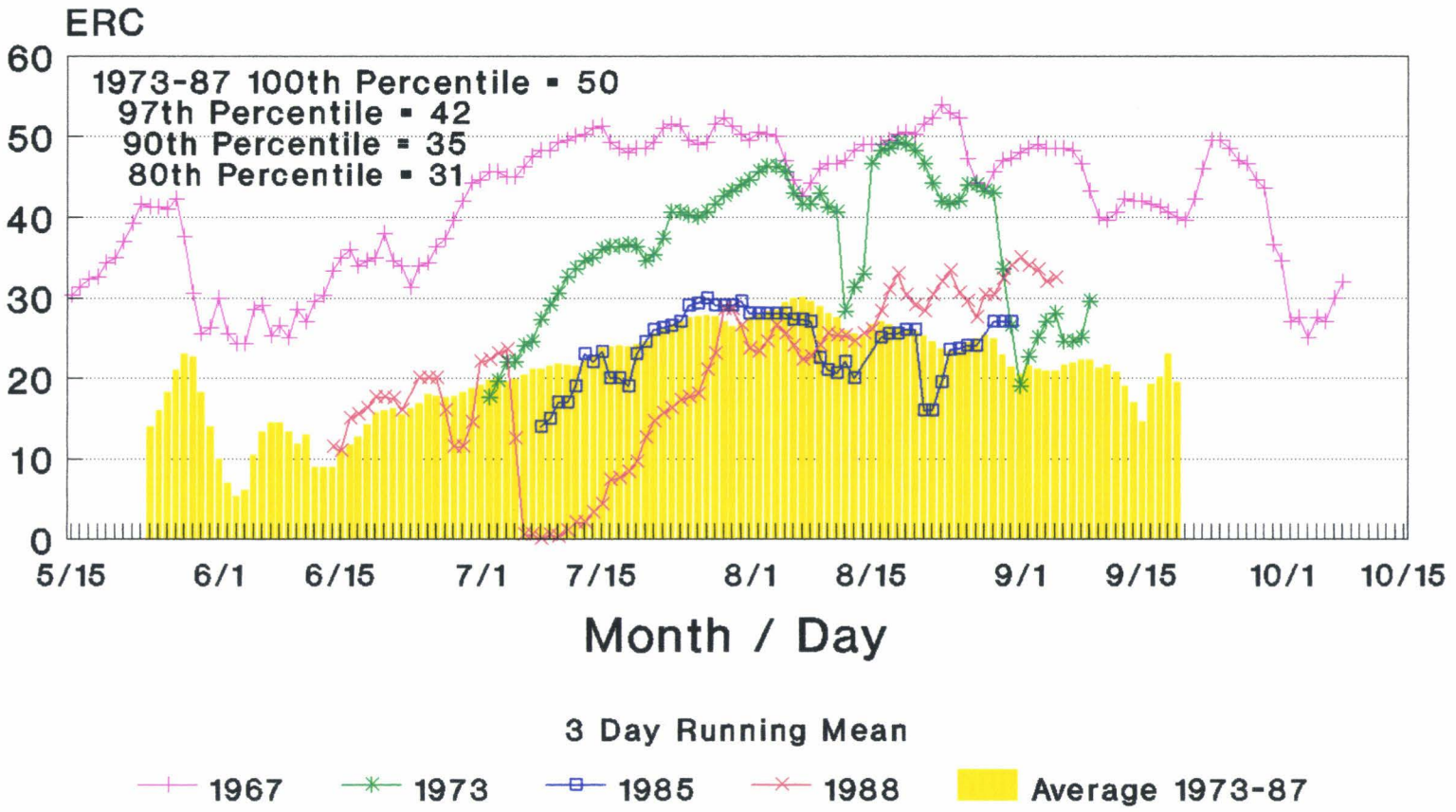
Energy Release Component

The average 1973-1987 3-day running mean at the Polebridge Ranger Station has a bimodal distribution with peaks occurring on May 28th (23.0) and again on August 7th (30.1)(Figure B-1). The first peak arrives after a brief, but steady climb in ERC starting following the start of data collection. There is a rapid decline in fire danger following the May peak with the arrival of June rains dropping the index back into single digits. Starting about June 15th the ERC levels begin a consistent climb toward the second ERC peak and the upcoming fire season. The 80th percentile for this time period is 31, while the 90th is 35.

Only the 1967 severe fire season at this station had moved above the 80th percentile by the end of June. In fact much of the early spring of that year the 1967 ERC index was between the 70th and the 97th percentiles (based on 1973-87 data). The lack of moisture at this station during April and May of 1967 would almost establish a drought record for that period (only the April-May period in 1947 was drier). An ERC decline at the end of May indicated the final arrival of some of the moisture that other areas of Northern Idaho and Western Montana had been receiving in such great quantities that winter and spring (Fischer 1969). However the precipitation period did not last long. By the end of June the near record spring drought conditions indicated earlier became the driest spring recorded (1946-1988 records). This would also be the last precipitation to arrive at this station until September! On June 12 the 1967 ERC index again begun to build and would consistently climb to record establishing heights. On June 14th the 1967 ERC level passed the 80th percentile, the 90th percentile was achieved the next day, on June 29th the 97th percentile was reached and the ERC level would stay above this level until September 10th. Maximum 3-day running mean ERC values of 54.0 would be achieved on August 23rd after an actual ERC index value of 55 was reached. These values are higher than the 100th percentile based on the 1973-1988 years alone.

Figure B-1. Energy Release Component for the Polebridge Ranger Station, Glacier National Park; Seasonal Average 1973-1987, 1967, 1973, 1985, and 1988 severe fire danger seasons.

Energy Release Component
Polebridge Ranger Station (240210)



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ERC data collection for the 1973 season was begun on July 2nd, and steadily climbed from the initial measurements. On the third day of data collection this station exceeded the 1973-1987 season average. By July 11th the ERC levels had passed the 80th percentile mark, and the 90th percentile was reached on July 14th. The steady index climb temporarily stalled on July 16th and held relatively steady for six days before again resuming it's upwards ascension. On July 29th the index passed the 97th ERC percentile level. The index stayed above this level until August 7th when a sharp down-turn occurred dropping ERC levels back below the 80th percentile and only slightly above the seasonal average. A very rapid recovery saw the 80th percentile level regained on August 13th, and the 90th and 97th percentiles passed on August 15th. The 100th percentile level was reached on August 17th when the actual ERC value hit 50. The highest 3-day running mean for the index would occur the next day, August 18th when the ERC index reached 49.3 for the 1973 fire season peak ERC reading. These values would be the greatest height attained by this index, at this station, for the next fifteen years. From this date there was a gradual decline in ERC values until a precipitous decline began on August 30th. By September 1st the index had returned to normal seasonal levels. A short period of index recovery was to occur before data collection ended for the season.

In 1985 fire danger data collection did not begin until July 8th at the Polebridge Ranger Station. On this same date much of the Northern Region was already experiencing extreme fire danger with nine major fires burning. This was also the day that the Regional Incident Coordinating Organization (RICO) for the Northern Region was activated. High pressure had been over the region for the past week and scattered afternoon thunderstorm activity was igniting new fires. On July 9th lightning started 53 new fires, mostly in the Selway-Bitterroot Wilderness along the western Montana - northern Idaho boundary. July 10th saw 30 new fire starts, and on the 11th another 51 lightning caused fires were reported with many areas exceeding their 90th percentile ERC level. Afternoon temperatures across the region were in the 85F to 100F range (Bushey and Goens 1985). ERC levels at the Polebridge Ranger Station rapidly climbed, gaining the seasonal average by July 13th. While lightning continued to cause new fire starts west and south of Glacier National Park a weak low pressure system brought some limited moisture to the park area, but only more lightning and strong gusty winds elsewhere. ERC levels dropped slightly with this slight increase in fuel moisture measured at the Polebridge Ranger Station and then continued to gradually climb regaining the seasonal average and closely tracking with the average. More moisture tracked to the south on July 24th leaving the Polebridge area unaffected, Kalispell received 0.28 inches, Glacier View Ranger Station 0.49 inches, Whitefish 0.33 inches. Peak ERC levels were attained on July 27th when the ERC level reached 30.0, just short of the 80th percentile level. ERC's near this level were maintained for twelve days before beginning to drop for the season. On August 1st a significant band of precipitation extended from Canada down to the Payette National Forest in Idaho. Extensive cloud cover over the Northern Region caused elevated humidities. On August 2nd this system was tracking to the northeast causing precipitation into southwestern and extreme western Montana. NFDRS stations across the region began to plummet in their Fire Danger indices ending the fire season at these locations. By August 3rd the rain had soaked the Lolo, Kootenai, and western portions of the Flathead National Forests. Light rains had fallen in Kalispell and Polson. On August 4th wetting rains from the Pacific weather disturbance continued over most of the region, but were still having little impact in the vicinity of Polebridge. On August 5th the system moved out of Montana and a high pressure ridge returned. On August

7th another Pacific weather front followed by low pressure moved across northern Idaho and western Montana. The front brought winds and scattered rains. A strong cold upper air low over Victoria, B.C. was slowly moving southeast, causing snow to be predicted for Glacier National Park above the 6,500 ft msl level. August 8th found snow reports coming in from Glacier National Park, the Swan and Mission Mountain Ranges, and along the eastern Rocky Mountain Front Range; also this date saw the first significant downward movement of the Polebridge ERC level. The ERC level decline at this site was considerably less dramatic than the rapid drops experienced at many other stations in the Northern Region, and Polebridge was also able to maintain its elevated ERC level longer than most other stations. On August 14th high pressure moving down from Canada had cleared out the clouds and brought temperatures back into the 70's, but another cold weather system was heading down behind the high pressure. The 1985 fire season had come to an end and while this was a severe fire danger season in other locations of the Northern Rocky Mountains it was not at this particular station.

ERC index readings for the 1988 season start on June 14th and for the next twelve days tracked fairly close to the 1973-1987 season average. June 26th through the 29th saw thunderstorm activity and precipitation across much of the Northern Region and southern Canada causing the ERC level to decline back below the seasonal average. After a short period of recovery back to near the seasonal average ERC level a return of rainy conditions throughtout the Kalispell-Glacier Park region on July 3rd - 5th caused the index to begin to plummet. Scattered showers and high humidities kept the ERC index down until about July 14th when a return to warmer, dryer conditions began. It would take until July 29th before the 1988 ERC index finally returned to slightly above the 1973-1987 average ERC level for that particular time of year. After a few days slightly above, the index again dropped below the seasonal average as scattered thundershowers again passed through the region for several days. On August 14th a building trend returned to the ERC index and would continue, with some fluctuations, until the station was abandoned September 7th as the Red Bench Fire swept through the Ranger Station. The 1988 ERC index climbed above the 80th percentile three times, dropping back to slightly lower levels twice during this final end of the season climb. The 90th percentile was attained on September 1st, the highest ERC level for the season, before declining again slightly. The 1988 season at this station never achieved the high ERC fire danger ratings attained by the 1967 and 1973 seasons.

All the severe fire seasons used in the comparison drop by various amounts during the first ten day period of August, and except for 1985 the seasons begin to climb to new heights. Severe season peak, or near peak ERC levels are reached during the third ten day period of August in 1967 and 1973, followed by another drop in ERC levels (this is earlier than the average ERC peaks during the 1st ten day period of August). The 1988 season exhibited a small decline during this period from a passing frontal system. At this point in time the 1973 season came to an end, leaving only the 1967 and 1988 seasons to again rebound. The 1967 season continued well above the 90th percentile level through the end of October before starting its final season ending decline. The station in 1988 after reaching a recorded peak in early September was abandoned before the Red Bench Fire passed through. If ERC data had been maintained at the site, it is unlikely that after the arrival of snow and rain on September 10th if the index would have recovered to much above the seasonal average during the following fall days of late September and October.

Burning Index

The BI at the Polebridge Ranger Station fluctuates considerably under the influence of periodic wind events during the fire seasons (Figure B-2). Most of these fluctuations are lost when the average values for the 3-day running mean of the 1973-1987 seasons is produced. The BI at this station is bimodal with peaks occurring on May 28th (31.3), and August 5th (29.7). BI variation surrounding the first peak date is dramatic dropping sharply reaching a low BI value within six days, then fluctuating for eleven days before beginning the steady climb toward the second peak during the summer months. The second peak BI period appears more rounded on the graph because of the gradual nature of both the build-up period and the post-peak decline. During the last days of August a short lived build-up in the BI again occurs attaining a value of 28.1 on August 29th. This period during the last days of August is persistent enough in the index record to appear in the seasonal average over the fifteen year record. The BI then rapidly returns to previous levels and remains relatively static over the next eleven to twelve days during the first half of September before resuming the season ending decline.

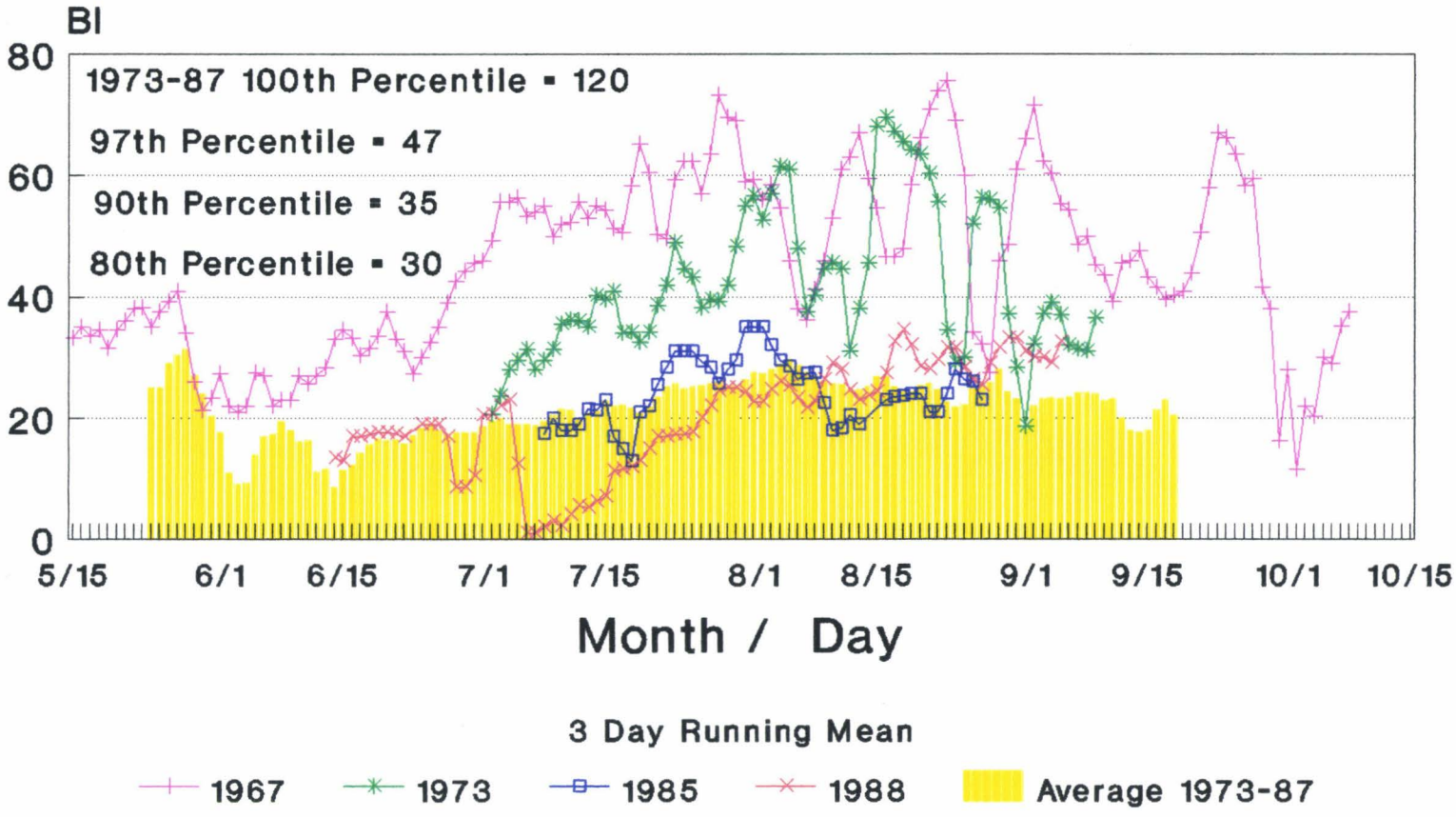
BI is not used as a prescription guideline in most prescribed fire management plans, principally because of its day to day variability. However, percentile levels have been calculated using the 1973-1987 historical data. The 80th percentile level occurs at a BI of 30, while the 90th percentile is only slightly higher at 35. The 97th percentile level is a BI of 47. The 100th percentile for the period is noted for the 1973-1987 period as 120. Examining the NFDRS output for this index from the Polebridge Ranger Station leads me to postulate that the 120 may be due to an accidental data entry. The upper boundary for the 99.9th percentile is a BI of 72 without any apparent readings until the 120 mark was recorded. An examination of the historical record for that reading would be necessary to determine its validity.

During the early portions of the 1967 severe fire year BI fluctuated from the 80th percentile level to slightly above the 90th percentile level from May 14th through May 28th before dropping back down to the seasonal average for the time period. However, as the seasonal average trend continues to decline the 1967 spring BI values tended to level off with minor fluctuations just beneath the 80th percentile level. The 1967 summer season build-up began on June 10th, earlier than the seasonal average. The spring build-up was steady, passing the 80th percentile mark again on June 14th, then the 90th on June 20th before a short decline dropped the index to slightly below the 80th percentile on June 23rd. The next day the index was again at the 80th percentile level and was beginning a remarkably steep climb as the month came to an end. On June 26th the 90th percentile level was again attained, and by July 2nd the index had climbed above the 97th percentile. This rapid build-up matches a similar build-up in the ERC index during this period. The apparent lack of any fluctuation during this rapid BI climb shows that the index increase was due principally to dramatic deceases in fuel moisture levels and not the influence of wind. Records indicate that 10-Hour Fuel Moisture during this period dropped from 11.6% down to 4% at the Polebridge Ranger Station, a decline of -0.95% per day! The 1967 BI index became relatively static on July 6th and remained so until July 18th when the index started to make large, erratic fluctuations of ever increasing BI levels. This pattern is characteristic of the BI index during increasingly warmer, drier conditions with periodic wind events. This pattern continued until July 23rd when a BI peak was attained and then the index began a downward trend falling over ten days to slightly above

Figure B-2. Burning Index for the Polebridge Ranger Station, Glacier National Park; Seasonal Average 1973-1987, 1967, 1973, 1985, and 1988 severe fire danger seasons.

Burning Index

Polebridge Ranger Station (240210)



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the 90th percentile level on August 7th. This period of decline corresponds to rising fuel moisture levels achieved with increased relative humidities, no rain fell at this station during July or August. As soon as the atmosphere began to dry the BI index returned to previous levels in three days, peaking in another 3 days before another short episode of increased relative humidity again caused a large fluctuation in the index. This time the index only fell to just below the 97th percentile level. In another six days (August 23rd) a new peak was reached which would prove to be the high BI value for this fire season (75.6). Following the season high value a fall of 48.0 index points over 5 days to just below the 80th percentile mark marked another period of high relative humidities and responding fuel moistures. Over five days the index regained its previously lost high value peaking on September 2nd, to be followed by a period of initial higher relative humidities and finally some precipitation resulting in a more gradual decline on the index graph. The 1967 season would recover later during September, but this was the turning point for the fire season.

From the start of BI data collection in 1973 on July 2nd the index steadily climbed as environmental conditions became drier. Periodic wind events added minor fluctuations as the seasonal average for the time period was rapidly left behind. The climb stalled on July 14th after the 90th percentile had been past the previous day. After two days of higher relative humidities and a stagnated index the BI fell for three days under the influence of precipitation and rising fuel moistures to slightly above the 80th percentile level. When the index started its up turn it only took four days to achieve a level as if the short decline had not even taken place. This type of pattern would continue at this station through out the 1973 season with the index steadily climbing to new heights after short periods of increased fuel moisture causing the index to decline rapidly. On August 16th the index hit it's peak for 1973 (69.6) as the ERC index continued to move upward for several days before peaking under calm, warm, dry conditions. Initially the BI declined only gradually as fuel moistures remained static, but as moisture arrived the index fell quickly and stayed down for three days. The season made one last attempted to regain lost fire danger, again moving past the 97th percentile level before dropping back to the seasonal average. Continued warm conditions during the first 10-day period of September in 1973 caused the index to climb above the seasonal average, but the index could not recover its earlier height.

As exhibited previously by the ERC index, the 1985 season BI index at the Polebridge Ranger Station fairly closely followed the seasonal average with periodic fluctuations above or below the average. The index did briefly in late July and early August first move above the 80th percentile level, then reached the 90th percentile (1973 season BI peak value of 35 on August 1st and 2nd). These were brief index rises which then returned to the seasonal average.

Burning Index levels started the 1988 season following very closely to the seasonal average between the start of data collection on June 14th and June 27th. After a brief drop and then a rise in the index values, the 1988 BI fell to a value of 1.0. It would take until August 9th for the BI to again exceed the seasonal average during which time the index was consistently lower than any other recent severe fire danger season. Even below the uneventful 1985 season at this station. The 1988 index had difficulty climbing and staying above the seasonal average for mid-August and briefly attained a season high value of 34.6, just below the 90th percentile, on August 18th before again dropping back to the average. However, as the seasonal average during this time of the year was on a gradual decline, the 1988 season BI was steadily

struggling to climb higher and fluctuating about the 80th percentile level. The 3-day running mean on September 5th indicated a slight upturn in fire danger (32.5) and was the last 3-day running mean value. The actual BI value for the afternoon of September 6th was 40 indicating the beginning of the wind event which helped to create the Red Bench Fire. This was the last data collected before the Ranger Station was abandoned.

Thousand Hour Fuel Moisture

Seasonal average Thousand Hour Moisture measurements during late May and early June at the Polebridge Ranger Station are at the measured season high of between 24 - 26% (Figure B-3). Average peak moisture is actually measured during the first few days of June after which there is a steady decline in large particle fuel moisture values of approximately -0.12% per day. The seasonal average low moisture reading is attained on August 9th (17.5%). After the low reading, moisture levels increase at a rate of about +0.06% per day attaining a late season moisture peak of 20.0% on September 19th. Data collection does not extend beyond this date to indicate if the Thousand Hour Fuel Moisture values have a characteristic fall dry period at this station. Frequently in late September and early to mid-October warm, dry autumn weather temporarily reverses the trend of increasing moisture of the large fuel particles in the Northern Rocky Mountains (see Thousand Hour Fuel Moisture; Park Headquarters, Spotted Bear Ranger Station, and Spotted Bear Lookout in this report)(Bushey 1990).

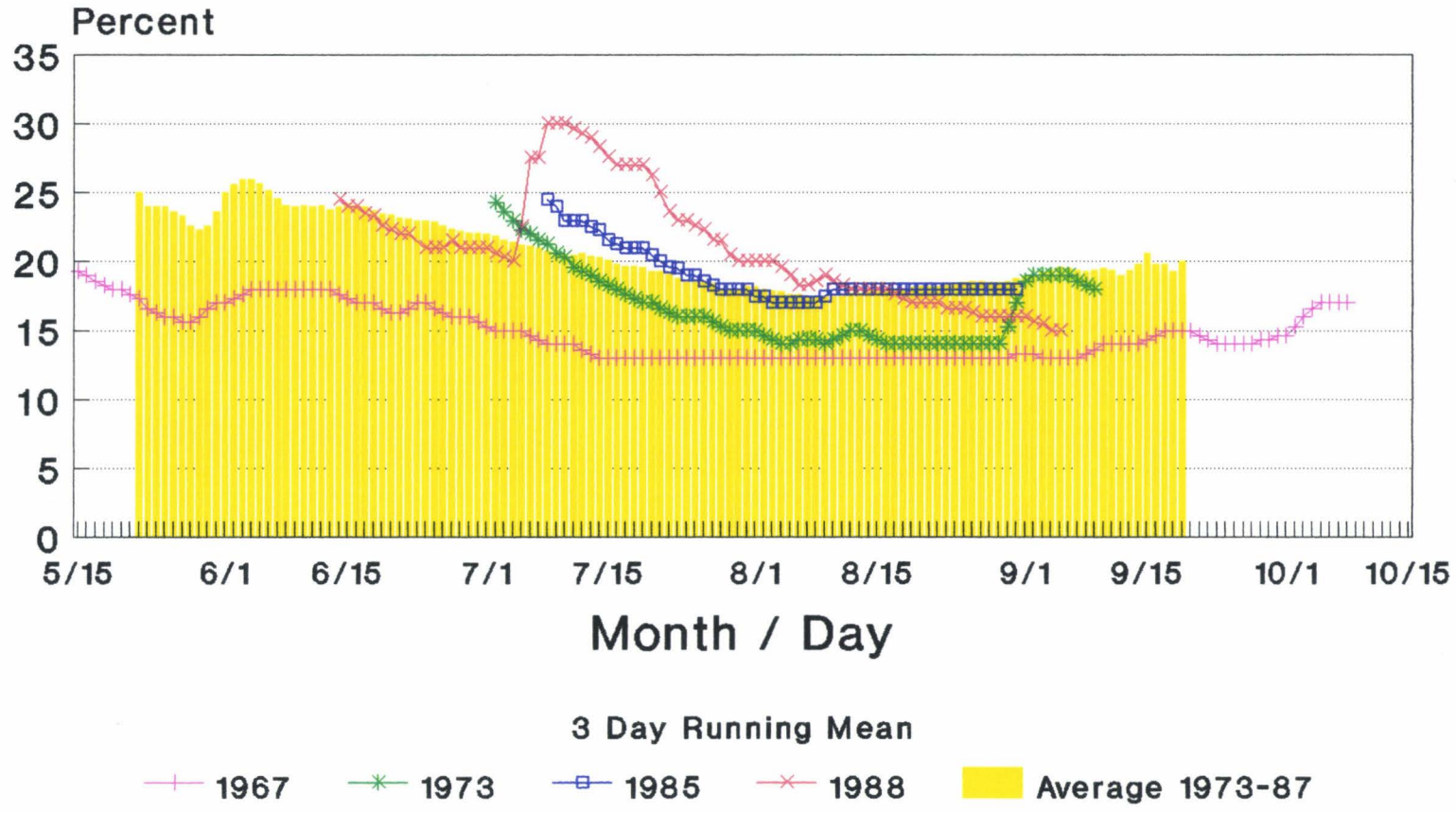
Of each of the recent severe fire danger seasons examined only the 1967 early season Thousand Hour Fuel Moisture values began below the seasonal average. May 15th found 1967 moisture level at 19.3%, approximately 6-7% below the average for the 1973-1987 historical record. The moisture level at this early time of the year was already declining rapidy at about -0.3% per day down to 15.6% on May 28th. Moisture values rose back to 18.0% in the first 10-day period of June with the arrival of spring moisture, but by June 14th the effect of these rains ceased and the drying cycle for the rest of the summer began. Between June 14th and July 14th, when the 1967 season low moisture value of 13% was reached, moisture levels dropped at an average of -0.16% per day. The 1967 season would remain at approximately this low level for a period of 56 days, until September 8th. Following this date moisture increased at the slow rate of about +0.12% per day. The entire 1967 season would remain below the seasonal average for this index. No other severe fire danger season at this station would attain such a low moisture level reading.

The 1973 season did not drop to the level of season average until July 9th as the moisture level continued a rapid, steady decline of about -0.38% per day. A low moisture value of 14% was reached on August 4th and fluctuated within 1% of this reading until August 30th, a period of 27 days. Following August 30th a rapid increase in fuel moisture levels took place gaining +1.25% per day over four days. This precipitation induced rise in moisture levels brought the 1973 large particle moisture levels back up to the seasonal average.

Thousand Hour Fuel Moisture did not drop to the seasonal average in 1985 until July 26 at 18.6%. Throughout July and early August the large fuel particles lost moisture at the steady rate of -0.27% per day. On August 3rd the 1985 season low value was reached of 17.0%, this level was maintained for seven days before moisture levels increased slightly. From the time that the 1985 moisture level reached the seasonal average through the end of the 1985

Figure B-3. Thousand Hour Fuel Moisture for the Polebridge Ranger Station, Glacier National Park; Seasonal Average 1973-1987, 1967, 1973, 1985, and 1988 severe fire danger seasons.

Thousand Hour Moisture
Polebridge Ranger Station (240210)



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season the Thousand Hour Fuel Moisture level followed approximately the seasonal average.

This index for the 1988 season is considerably different than the other previously discussed seasons. Measurements were begun on June 14th, and from that date until July 4th large particle fuel moisture very closely followed the seasonal average trend but was gradually becoming dryer at a rate of -0.21% per day. On July 5th the arrival of precipitation started a four day period of rising moisture levels at +2.5% per day, very quickly sending the 1988 moisture index well above the seasonal average. The index would remain above the average for a period of 43 days, until August 17th. On this date the declining (-0.30% per day) moisture again intersected the seasonal average. The seasonal average value had already starting to rebound from it's summer minimum. However, the 1988 index would continue to decline, at a rate of approximately -0.14% until readings ceased to be taken because of the destruction of the station. A 1988 low moisture value of 15.0% had been attained on September 4th and was maintained through the 6th rivaling only the the 1967 season for dryness in early September during the years examined.

PARK HEADQUARTERS, GLACIER NATIONAL PARK, WEST GLACIER, MONTANA

Energy Release Component

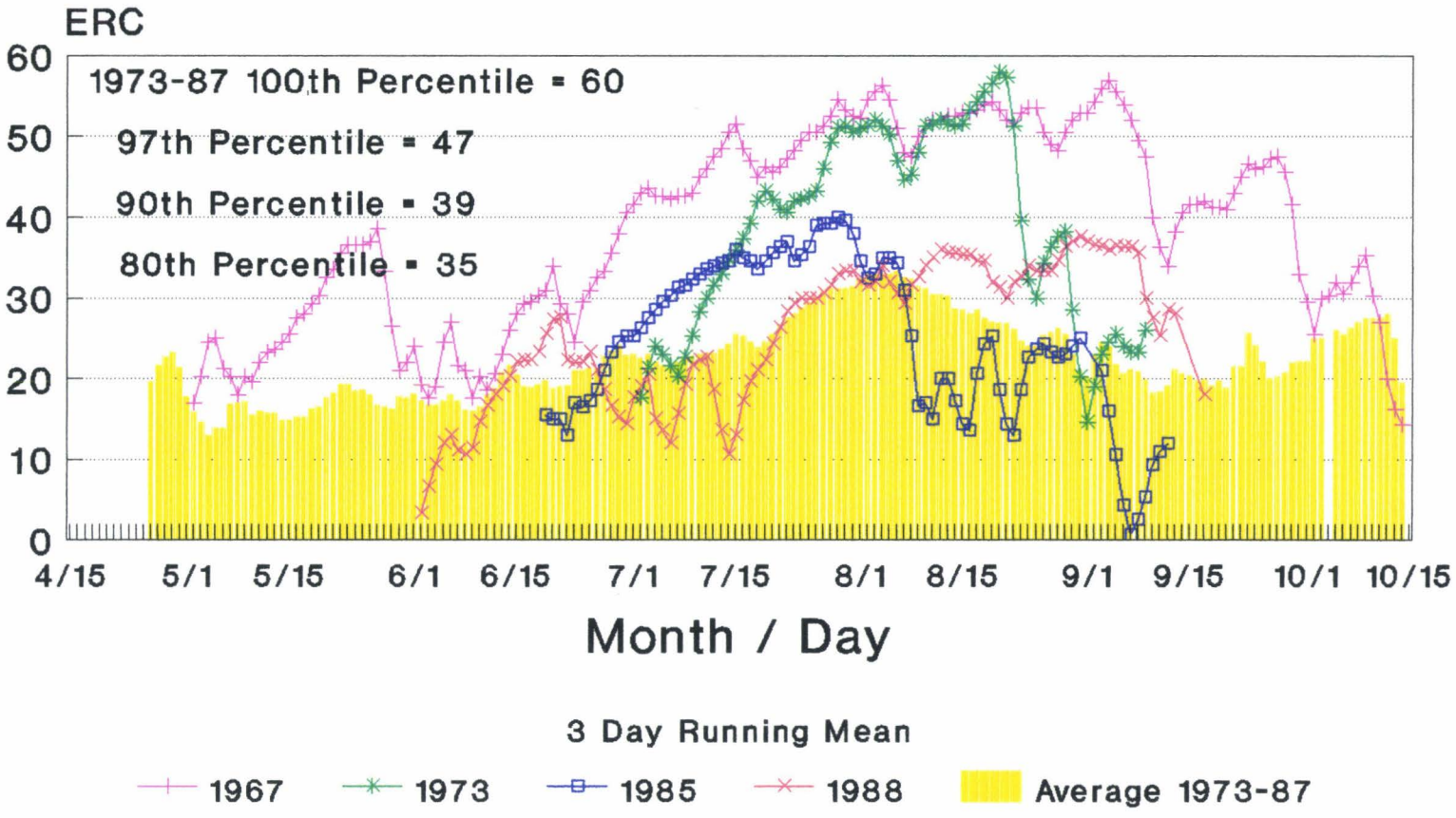
The record for Park Headquarters, Glacier National Park is of longer seasonal duration than the Polebridge Ranger Station running from late April through mid-October (Figure B-4). The average, 1973-1987 3-day running mean ERC at the Park Headquarters tends to be irregular in its pattern with numerous small rises and dips as the fire season progresses though trimodal peaks in late April, early August, and mid-October. The greater degree of irregularity shown by the seasonal average ERC Index at Park Headquarters and not visible in the seasonal average ERC Index from the Polebridge Ranger Station reflects the greater occurrence and influence of frontal systems and precipitation events at the Headquarters station. This irregular pattern is also reflected in comparisons of the other fire danger indices as well.

The 80th percentile level produced from the 15 years of averaged seasonal data is at an ERC level 35. Only during early August does the average ERC values approach, but not quite reach the 80th percentile level (33.3). The two other seasonal average ERC peaks are of even lower stature, with the highest of these being the one in mid-October and rising to 27.6. The 90th percentile level from this station is an ERC Index value of 39, while the 97th and 100th percentile levels are 47 and 60 respectively.

The 1967 severe fire season as measured by ERC was considerably above the average ERC measurements. The 1967 spring season measurements started at the Headquarters station on May 2 and rapidly moved above the seasonal average and establishing a late spring ERC peak on May 27th with a reading of 38.6, just below the 90th percentile mark. South slopes had lost their snow cover in the vicinity of the station (Bunney 1967) and 10-Hour fuel moistures dropped down to 5.3% (normal for the time of year is 16.8%). A rapid rise over several days in 10-Hour Fuel moisture levels starting on May 27th indicates the arrival of precipitation, and the ERC Index dropped back down to just above the seasonal normal. Ten-Hour fuel moisture levels climbed back to above normal eventually attaining 19.0%. Continued periodic moisture kept the index from resuming it's rise in earnest until June 12th. It is apparent from the ERC levels before and just after this date that the moisture received at this station was just barely keeping the index value suppressed. As soon as the moisture ceased the index

Figure B-4. Energy Release Component for the Headquarters station, Glacier National Park; Seasonal Average 1973-1987, 1967, 1973, 1985, and 1988 severe fire danger seasons.

Energy Release Component
Headquarters, West Glacier (240207)



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rapidly rose again to just below the 80th percentile level before again being driven back down by the new arrival of some precipitation on June 21st. With each decline it would take two to three days before the index would start to rebound, and each rebound appeared to be stronger than the last. On June 24th the index began it's rapid climb toward the summer maximum ERC levels. The 80th percentile level was again crossed on June 28th, then the 90th was passed on June 29th. It would take until July 12th for the index to pass the 97th percentile level, and it would again briefly dip below that mark before again continuing to rise. During this particular dip in ERC levels a thunderstorm was passing through the region near the station. This storm had only "light" precipitation and started 5 fires, none of which achieved significant size (Bunny 1967). The climbing 1967 ERC Index matches the undulations of the seasonal average very well, except at a greater height. When the seasonal average dips or stagnates, the same pattern appears on nearly the same dates during the 1967 season at this site. While the seasonal average maximum ERC arrives on August 6th, the climbing 1967 index peaked on August 4th (56.3) before beginning a short lived decline. Following this decline is where the 1967 season pattern differs from the seasonal average. The seasonal average enters in to a period of decline, while 1967 would continue to climb to establish new heights in fire danger. The station "simmered under predominately clear skies, warm temperatures, low relative humidities, and negligible precipitation" during the early days of August. On August 7th a thunderstorm developed which started a fire in the Kintla drainage near the Canadian-American Border. This fire would remain undiscovered until August 11th when winds from a passing cold-front enabled an aerial observer to see the spreading fire (Bunney 1967). After briefly dropping down to slightly above the 97th percentile level on August 8th following this thunderstorm, the ERC values moved upward at a slower rate. Elevated relative humidities caused the slow down in the ERC rate of climb, but these same high atmospheric moisture levels helped to create storms which started new fires. On August 11th and 12th a dry lightning storm associated with the previously mentioned dry-cold front passed just west of the Continental Divide starting 31 new fires and burning in excess of 12,000 acres. On August 17th another dry-cold front passed through the area with associated strong winds further spreading the fires, especially in the lower portion of the North Fork of the Flathead River. August 23rd experienced a weak Pacific front passing through the area during the afternoon. This front was accompanied by dry lightning storms and variable, strong, gusty winds. Winds along ridgetops were reported to be 40 to 60 MPH. Fire fronts expanded rapidly with considerable spotting especially on fires in the vicinity of Huckleberry Mountain, 9.5 miles northwest of the Headquarters station. Another frontal system arrived on August 26th with local gusty winds (Bunney 1967). Following the passage of this front the ERC Index resumed climbing. Another dry cold front passage on September 2nd with strong winds had no effect on the ERC levels at this station which continued to climb. This weather front contributed to a significant, short-term catastrophic fire event on the Sundance Fire in northern Idaho which burned over 50,000 acres (Anderson 1968; Finklin 1973). On September 4th the 1967 ERC maximum 3-day running mean was reached of (57.0). An actual ERC value of 58.0 was achieved on this date before rising relative humidities, and eventually the arrival of some moisture caused the index to begin to decline. It would take until October 2nd before the 1967 ERC level approached the seasonal average, but even then an attempt to rebound is observed before finally dropping below the seasonal average on October 11th.

ERC Index levels at the start of 1973 began beneath the the seasonal average in early July. However, the index soon began to climb rapidly leaving the seasonal average behind on July 8th. On July 15th the ERC level rose past the 80th percentile level, and two days later was past the 90th percentile level. By July 28th the continuously climbing index exceeded the 97th percentile level. During late July and early August the index stabilized between values of 50 to 52. This is typically the time of year during which the seasonal average reaches an ERC maximum then begins to decline. Right on schedule on August 7th, and also following the 1967 season pattern, a precipitation event brought down the ERC level and rose 10-Hour fuel moisture levels from the low of 3% experienced a few days before to 11%. Following the moisture event a return to warm and dry conditions contributed to a rebound in the ERC value. ERC levels climbed steadily until reaching a season 3-day running mean maximum level of 58.0 on August 20th. Actual ERC level on this date was 59.0, a single point higher than achieved during the 1967 season. Following this maximum ERC value the 10-Hour fuel moisture measurements from the station start to show an initial slow increase in moisture levels, then on the second and third days dramatic increases indicating a major wetting precipitation event. This rain caused the ERC level to decline back below the 80th percentile level, and while the index would try to briefly rebound this would turn out to be the season ending event at this station. A return to near or below seasonal averages occurred on August 31st and lasted the remaining data collection period.

ERC levels during the early part of 1985 remained below the seasonal average until June 29th. The index made a steady and sustained climb attaining the 80th percentile level on July 16th, and the 90th percentile on July 26th. The seasonal maximum 3-day running mean for 1985 was reached shortly after this on July 29th (40.0). Weather during this period was very warm with above normal temperatures, and little or no precipitation, as a hot, dry, and stable air mass covered the region. On July 30th a storm tracking northward moved from central Idaho in to northcentral Idaho and southern Montana producing significant precipitation in southwestern Montana and along the Rocky Mountain Front Range. Cloudy, cool conditions persisted throughout the day as far north as Missoula in western Montana (Bushey and Goens 1985). On July 31st ERC levels in the northern portion of the Montana remained stabilized as relative humidity levels stayed high. Ten-Hour fuel moisture levels were beginning to rise from the elevated humidity levels but rain had still not arrived at the station as much of northwestern Montana escaped the wetting rains covering much of the rest of Montana and northern Idaho. ERC levels had returned to near normal seasonal levels by August 2nd. On August 8th a strong, cold upper air low moved down from Canada causing snow to fall at the higher elevations of the Northern Rocky Mountains including Glacier National Park. August 9th found the cool northwest upper air flow and higher humidities start to cause a small decline in the ERC levels at the Headquarters station. Additional snow fell down to the 5,500 ft msl elevation in Glacier National Park overnight of August 13th and 14th. This event was from extensive cloud cover which covered the entire region of Montana and northern Idaho. The next day on the 15th a Canadian surface cold front moved across the region and the ERC level at Headquarters started to tumble to well below the seasonal average. The station would record several attempts as the season progressed for the ERC level to move back up to the seasonal average. But each attempt was unsuccessful and short-lived.

When ERC data collection was begun in 1988 (June 2nd) the index was well below the seasonal average for the time period. This was principally the

result of a much wetter than normal month during May at the Headquarters station. However, the index proceeded to climb rapidly toward the seasonal average which it attained on June 11th. The seasonal average was followed for several days and then the index climbed up to 27.6 on June 21st and it appeared that the potential existed for an early severe fire season. A weather system with some rain dampened the fuel and caused the index to return back to the seasonal average. The ERC Index would fluctuate below the seasonal average during the first half of July as reoccurring precipitation events drove the ten hour fuel moistures above levels normally observed even during the wetter spring months of May and June. On July 15th the index finally started to rebound without a weather event to stall the fuel drying processes. The seasonal average was regained on July 22nd; a time when the other, previous severe fire danger seasons were already well under way. The index followed the seasonal average through August 9th as the average peak fire danger was obtained and the decline begun. The 1988 index declined slightly from increased relative humidities and light rains causing a rise in fuel moistures. The Pacific weather front had arrived on August 6th causing cloudly to partly cloudy conditions across the region. On the 7th the system was beginning to move east with increased wind speeds behind the front. Behind the front the atmosphere was drying and stabilizing, and a return to sunny skies and unseasonably warm temperatures took place on August 9th. These drying conditions contributed to a renewed climb in the 1988 ERC Index. For the first time in 1988 the 80th percentile level was reached on August 11th. The index stabilized at this level for six days then dropped as a weak and stationary weather system extending from Glacier National Park to Boise caused cooling, increased relative humidities, and increased winds behind the front. As the front finally moved east, the weather warmed in to the upper 80's (relative humidities in the upper teens) temporarily at the Headquarters station, only to drop again as another cold front moved down from British Columbia the evening of August 20th. Some instability in front of this system caused scattered showers in northwestern Montana, but mostly in the Kalispell and Glacier National Park area (0.01 inches at Headquarters). Behind the system daytime temperatures were dropping in to the low to mid 60F's. On August 21st a ridge of high pressure was moving in to the area from the Pacific, bringing with it unseasonably warm and dry daytime conditions. The ERC levels started to turn upwards again on August 22nd and by the 29th the 80th percentile level had again been passed. The strong, upper ridge of high pressure system developed over the western United States brought daytime temperatures in to the low 80F range, and relative humidities in the mid 20% range at the Headquarters station. A fast moving Canadian cold front on August 26th brought scattered showers to the park, but not the Headquarters station, and had little impact on the ERC level. The 1988 ERC maximum level was reached on August 31st at 37.6 and just slightly above the 80th percentile level. A slight downturn in the ERC level occurred on the September 1st after a weak upper level Pacific trough of low pressure producing gusty winds and slightly cooler temperatures had pushed through late the previous afternoon. On September 1st the ridge of high pressure started to rebuild bringing fair, dry weather. ERC levels remained essentially unchanged, hovering just above the 80th percentile level, as a dry cold front pushed through on September 7th. The ERC values started to drop on the 9th after another frontal system pushed down from Canada. This system brought much cooler air, cloudy skies, and higher relative humidities to the station. A return to the seasonal average occurred on September 17th, and rain was recorded at the station on September 18th as the 1988 season ended.

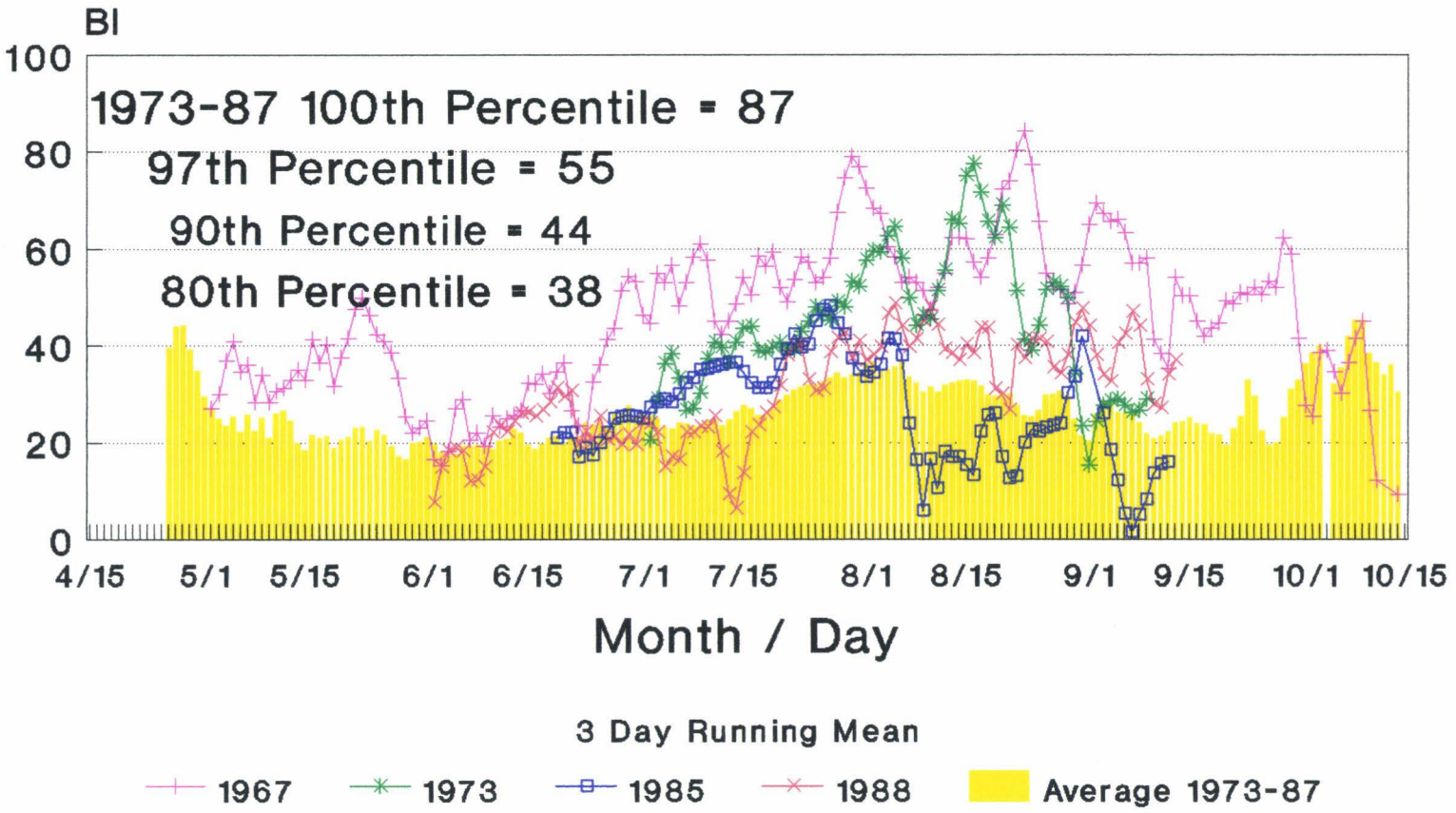
Burning Index

The 1973-1987 seasonal average for the Burning Index from the Headquarters station has a trimodal series of peaks through the season similar to the ERC Index (Figure B-5). The highest seasonal average readings are obtained in October (45.3), followed by late April (44.3). These two peaks coincide with relative dry periods of cured vegetation (May at low elevation sites follows snowmelt and precedes green-up, October has both summer dried fuel and frost killed vegetation) and high average wind speeds. May in particular can have some strong wind events. The normal fire season peak occurs in early August (36.7). August has a greater average wind speed than October, but fewer strong wind events than May; and has the warm, relatively dry conditions of summer. The 80th percentile for the 1973-1987 historical record from Headquarters station is 38, and the 90th percentile level is 44. The 97th and 100th percentile levels are 55 and 87 respectively.

The Burning Index during the spring of 1967 immediately climbed above the seasonal average and had passed the 80th percentile level for the first time by the fourth data collection date, May 5th. The index fluctuated considerably after this date and briefly passing the 90th percentile level on May 22nd, peaking the next day with a reading of 50.0, before dropping back down to the seasonal average on June 2nd. From that date until June 15th the index stayed near the seasonal average. The 15th saw a rapid rise in BI and a peak on June 20th (36.6). Precipitation forced a downturn of the BI on the 21st which then proceeded to briefly fall back to the seasonal average. Following that decline the index rapidly rebounded on June 24th with the 80th percentile level passed on the 26th. Two days later, on June 28th the 90th percentile level was passed; and on July 3rd the 97th percentile level. BI would fluctuate around the 80th to 97th percentile levels until July 28th when the index started a steep climb peaking at a 3-day running mean index value of 79.0 on July 30th (actual BI value for the day was 90.0). An eleven day decline in index values would then occur bring the BI back to just above the 90th percentile level on August 10th. During this time period of BI decline saw the passage numerous thunderstorms and finally a dry-cold front on the 11th and 12th which ignited 31 fires in Glacier National Park. BI again resumed the summer climb with the return to high pressure moving up to 62.3 before another dry-cold front caused the index to stumble a few index points. After obtaining a low value of 54.0 on August 17th (the day of the frontal passage) the index rebounded rapidly under the influence of winds behind the front, and then warmer and dryer atmospheric conditions. A 1967 BI 3-day running mean maximum value of 84.3 was attained on August 23rd. The actual BI value for the day was 89.0, and on the 24th the actual value was 90.0. The afternoon of the 23rd experienced a weak Pacific frontal passage which was followed by strong, gusty winds. After the frontal passage the index dropped back to above the 90th percentile then tried to rebound again. BI would peak again at 69.3 on September 2nd as another dry cold front passed through with peak morning winds of 44 MPH measured at Great Falls (Anderson 1968). It was this frontal passage which contributed to the short-term catastrophic fire run of over 50,000 acres on the Sundance Fire in northern Idaho. The presence of a reverse wind profile associated with a low-level jet point with winds in excess of 90 MPH above 24,000 ft msl, and at times greater than 50 MPH on the fire itself contributed significantly to the extreme fire behavior observed (Anderson 1968; Finklin 1973). After this weather event the index again fell with the final arrival of some moisture. BI would again climb, remaining above the 80th percentile until October 1st when it finally fell to below the seasonal average.

Figure B-5. Burning Index for the Headquarters station, Glacier National Park; Seasonal Average 1973-1987, 1967, 1973, 1985, and 1988 severe fire danger seasons.

Burning Index
Headquarters, West Glacier (240207)



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Right at the start the 1973 Burning Index promptly climbed above the seasonal average for early July and had passed the 80th percentile level by July 5th. After a brief drop back down below that level the index regained the 80th percentile on July 14th and would not drop below that mark for another 48 days. In a steady climb with only minor fluctuations the index rose past the 90th percentile level on July 24th and the 97th percentile on August 1st. A temporary peak of 64.6 was reached on August 5th before the index fell back to the 90th percentile on August 8th. A rapid rebound of the index followed that low point finally attaining the 1973 season maximum 3-day running mean of 77.6 on August 16th. Actual BI value for the date was 82 followed by 85 on August 17th. A decline of -15.3 points during the next three days occurred as slightly cooler temperatures and higher humidities followed declining wind speeds behind a frontal passage. Rain finally brought the index back below the 90th percentile. A brief rebound would occur followed by another dramatic decline to below the 80th percentile on August 30th and back to the seasonal average of the low 20's the following day. After a decline of 62.3 points during 16 days the 1973 season never significantly recovered in fire danger.

On July 2nd the 1985 BI value moved above the seasonal average and gradually climbed to a peak at 36.6 below the 80th percentile level on July 13th and 14th. A temporary decline in the index value occurred as cooler temperatures from overcast skies developed from a southwesterly upper level flow ahead of a Pacific weather system. Afternoon thunderstorms were a common occurrence during this period of unstable conditions, causing numerous new fire ignitions throughout the Northern Region. The dry, high pressure was rebuilding by July 18th with only scattered moisture from thunderstorms. By July 20th most afternoon maximum temperatures across the Northern Region were in the 90F-100F range. On July 21st the BI again moved above the 80th percentile. The next day, July 22nd, brought a peak to the climb just over the 90th percentile mark as a low pressure trough moving down from Canada brought winds but no moisture. BI dropped the next several days as humidity recovery and increased cloud cover followed the Canadian low pressure system. The index would attempt to rebound, achieving the 90th percentile level on July 25th. This date would also be the 1985 season maximum 3-day running mean of 45.0. The following date would have the highest actual BI value of 56.0 as high winds across northern Idaho and northwestern Montana occurred with a passing system in Canada. With a decline in wind speeds under the return of a hot, dry, stable air mass the BI index dropped to back below the 80th percentile level and the seasonal average. Winds from a weak Pacific weather disturbance would cause a small increase in the Burning Index on August 4th and 5th, but this was followed by a cold air mass, increased relative humidity and snow at the higher elevations, and eventually rain at the Headquarters station. A sharp decline to well beneath the seasonal average on August 7th would begin the early end of the 1985 fire season.

The 1988 BI values measured at the Headquarters station stayed at or below the seasonal average until July 20th, much later than any of the other recent severe fire danger seasons examined. The index moved above the 80th percentile level the next day, and pushed by winds from a frontal system sweeping into the region from British Columbia the 3-day running mean for the index peaked on July 23rd (actual high value for BI peaked the previous day during frontal passage). With the cooler temperatures, higher relative humidities, and light winds following the weather system the index fell back to the seasonal average. Another frontal system passed by the Headquarters station on July 28th causing another similar rise and fall in the BI values. This pattern persisted throughout the summer, with each subsequent rise in BI being slightly

higher than the last. The 1988 season maximum BI value was attained on August 5th after a frontal passage on the 4th, reaching 48.6 after the 90th percentile was passed on the 4th. On August 10th the index almost matched the season high value, reaching 48.0 before declining. A general declining trend was soon underway and the index returned to the seasonal average on August 19th and continued falling for another two days reaching a low value of 26.6. This low point corresponds to an extended period of high relative humidities and scattered thundershowers. With the rebuilding of high pressure the index rebounded moving back above the 80th percentile level. BI flucutated the rest of the summer season around the 80th and 90th percentile levels, climbing under the influence of periodic wind events. Each decline was slightly lower then the previous low point as fuel moistures steadily raised under the influence of shorter days, cooler nights, and higher relative humidities.

Thousand Hour Fuel Moisture

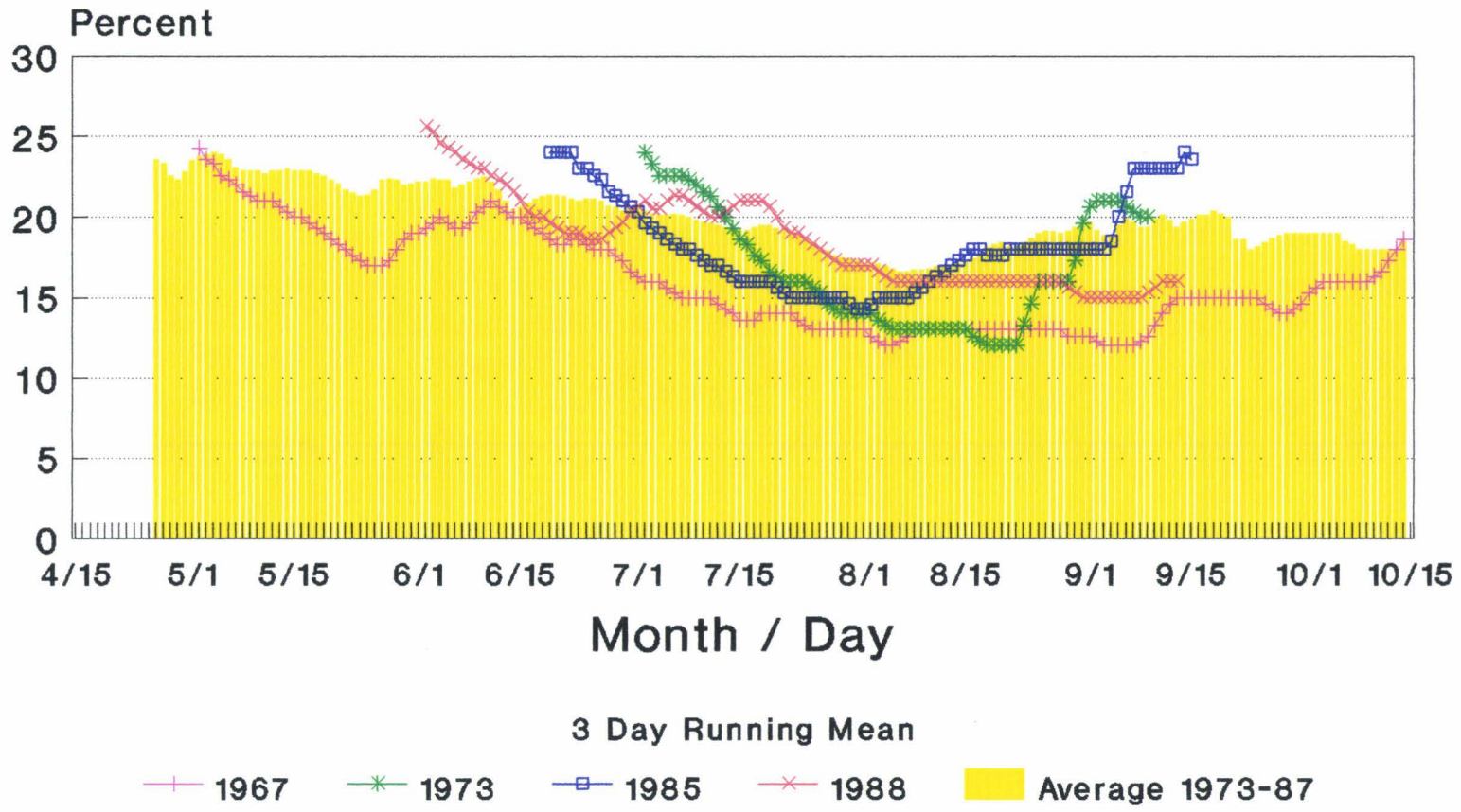
The Thousand Hour Fuel Moisture measurements at the Headquarters station begin with a seasonal average between 22-24% during late April - early May (Figure B-6). From about May 5th on this station experiences continual declines in Thousand Hour Moisture levels at a gradual rate of approximately -0.07% per day. The average summer low moisture level is reached on August 6th at 16.6%. Following this low value an increase in moisture is experienced (about +0.15% per day) until September 18th when a late season high moisture level is reached of 20.4%. After September 7th a return to drying conditions extends into October and attains the seasonal average maximum low moisture reading on October 8th of 18.0%.

The 1967 severe fire season at this station started a sharp decline below the seasonal average right at the beginning of data collection. From May 2nd until May 25th the index declined at the rate of -0.31% per day. Following a few days of no change the index then began to rise under the influence of late May and early June precipitation. This rainy period drove the large particle fuel moisture up from 17.0% to 21.0% at a rate of +0.26% per day, peaking on June 11th. A new period of gradual decline (-0.37% per day) then took place as the moisture levels dropped steadily toward their 1967 seasonal minimum value of 12.0% reached on August 4th. This low level was maintained for two days then climbed to 13% for an extended period. The Headquarters station would remain between 12 and 13% Thousand Hour Fuel Moisture content for 47 days until September 10th when the index began to recover moisture. It would take until October 13th when the index achieved a moisture content of 18% for the seasonal average to regained.

The 1973 season Thousand Hour Fuel Moisture levels at the Headquarters station remained above the seasonal average until July 14th. However as the index crossed the seasonal average it was doing so at a very rapid rate of approximately -0.53% per day. This represents one of the most rapid declines in moisture recorded from the recent severe fire danger seasons, and at this late time period of the season the decline would have to be rapid to achieve severe burning conditions before the onset of late summer moisture recovery. The index reached the 1973 season minimum value on August 18th at 12.0% with a final decline rate of about -0.13%. A total of 18 days would be spent between 12 and 13% Thousand Hour Fuel Moisture content before a rapid recovery took place. With the arrival of precipitation the index began to rise on August 23rd at a rapid rate of about +0.81% per day, achieving the seasonal average again on August 31st.

Figure B-6. Thousand Hour Fuel Moisture for the Headquarters station, Glacier National Park; Seasonal Average 1973-1987, 1967, 1973, 1985, and 1988 severe fire danger seasons.

Thousand Hour Moisture
Headquarters, West Glacier (240207)



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Moisture levels above the seasonal average were maintained in 1985 until June 30th as a steady, but gradual decline in Thousand Hour Fuel Moisture content took place at the Headquarters station. A decline rate of about -0.23% per day continued until the season minimum moisture level was reached of 14.3% on July 31st. Following that date the index rose at a rate of about +0.17% per day until August 21st at which time moisture levels stabilized at 18.0%. The seasonal average was reached prior to this date on August 13th. Another major precipitation event drove the index well above the seasonal average on September 6th.

Thousand Hour Fuel Moisture levels in 1988 dropped below the seasonal average on June 16th, much earlier than either the 1973 or 1985 seasons. Index levels declined at a rate of approximately -0.21%, paralleling moisture decline during the 1967 season. The arrival of precipitation started an upturn in moisture content on June 27th and a deviation from the 1967 pattern of moisture decline. This precipitation event returned the 1988 Thousand Hour Fuel Moisture content back above the seasonal average. It would not be until July 21st before the index would again drop back to the seasonal average, which it would closely follow in decline. Not until the seasonal average would start to regain moisture would the 1988 index deviate from this pattern, at which point the 1988 index stabilized at 16.0% for 24 days. On August 31st the index had dropped to 15.0% which level it maintained for nine days until September 8th. Index measurements ceased on September 13th after an upturn in moisture content was recorded.

SPOTTED BEAR LOOKOUT NFDRS STATION, FLATHEAD NATIONAL FOREST

This station is located on the Flathead National Forest just outside the boundary to the northern edge of the Big Salmon Unit of the Bob Marshall Wilderness complex. It is approximately 40 miles north-northwest of the Scapegoat Wilderness portion of the complex. This is a high elevation, short season station situated at about 7,200 ft msl. Besides the Silver King Lookout (7,771 ft msl) this is the only other high elevation NFDRS station still providing weather and fire danger information for the Bob Marshall Wilderness complex.

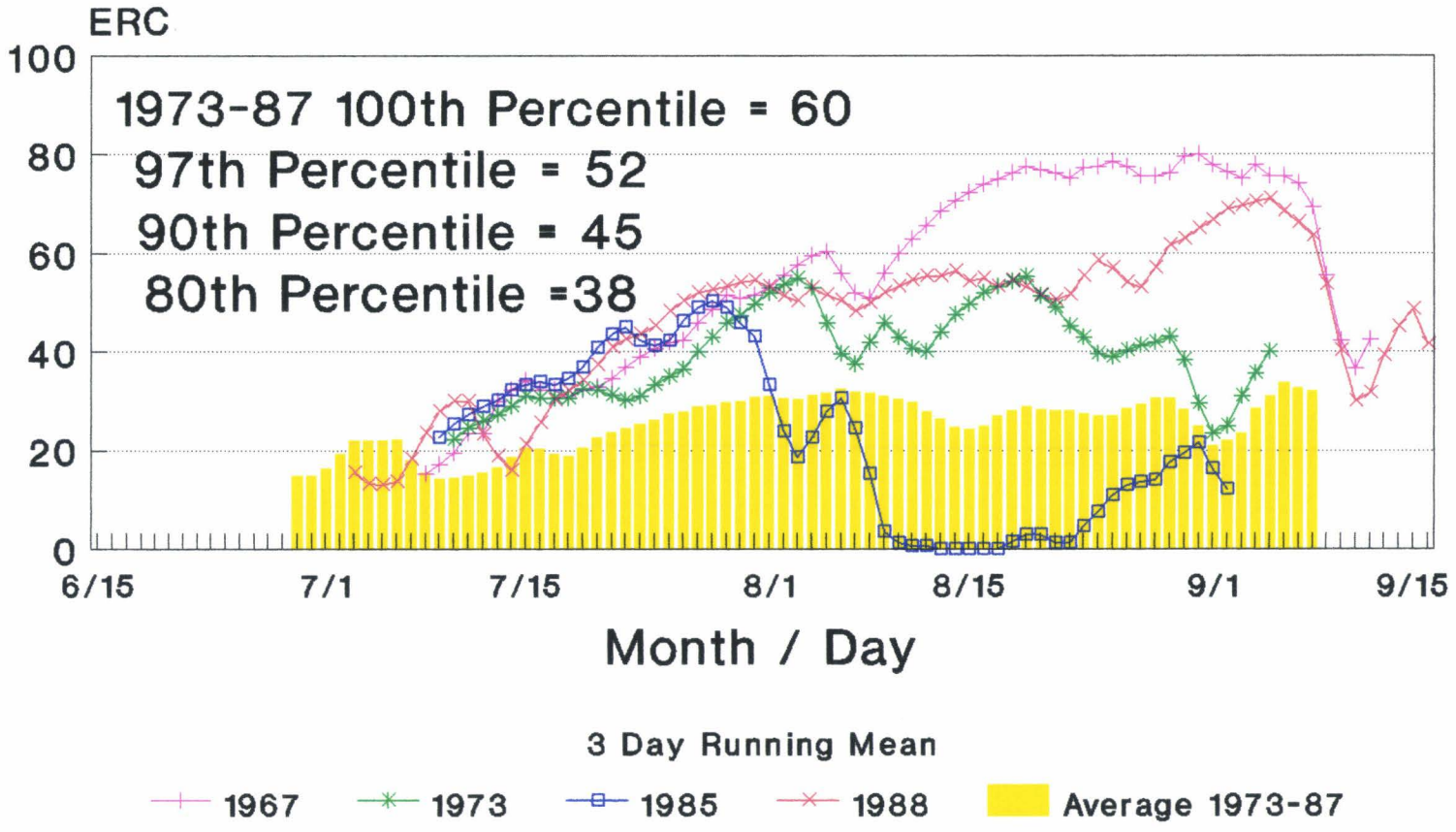
Energy Release Component

The lookout on top of Spotted Bear Mountain begins to climb in seasonal average ERC levels on July 10th (14.5)(Figure B-7). The increase in ERC levels are gradual, reaching a summer peak on August 6th (32.5). Following this early August peak the seasonal average ERC level undulates until reaching a late summer low value of 20.9 on September 1st. During the first ten day period of September the seasonal average ERC levels again begin to rise, attaining the maximum high ERC level of 33.8 on September 6th. This is the closest the seasonal average ERC values approach the 1973-1987 80th percentile level of 38. This station had the smallest variation in seasonal average ERC levels of all stations examined.

All four severe fire danger seasons documented for this station start to move above the seasonal average ERC level either immediately or shortly after that year's measurements are begun, between July 7th and July 10th. Only the 1988 ERC level rises and then falls briefly back to the average, all other seasons steadily continue their increase in ERC. On July 20, 1985 that season's ERC crossed the 80th percentile level, 1988 would be seen to do the same on July 21st. The 1967 season would wait until July 23rd to pass the 80th

Figure B-7. Energy Release Component for the Spotted Bear Lookout NFDRS Station, Flathead National Forest; Seasonal Average 1973-1987, 1967, 1973, 1985, and 1988 severe fire danger seasons.

Energy Release Component
Spotted Bear Lookout (240213)



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percentile, while 1973 would experience the longest delay crossing this demarcation line waiting until July 27th. All four seasons follow very similar trends in their ERC rise. The 1985 season was the first to reach a maximum ERC peak on July 22nd (45.00, 90th percentile level) and then began its season ending decline with the arrival of increasing humidity and finally rains. The remaining severe seasons also achieved the 90th percentile level within days of the 1985 season; 1988 on July 24th, 1967 on July 27th, and 1973 on July 29th, an interval of 8 days for all 4 seasons. Of these remaining severe seasons which continued to rise to the 97th percentile level (52.0), this boundary was reached at an even closer interval of 6 days; 1988 on July 27th, and both 1967 and 1973 on August 1st. The 1973 season would develop double maximum high ERC level peaks on August 3rd (55.0), and then again on August 19th (55.3), before starting the season ending decline. Both the 1967 and 1988 seasons would continue there upward ERC movement until later seasonal peaks were attained. 1967 would experience very rapid increases in ERC levels after August 1st, and by August 14th ERC levels exceeded 70.0. These high 1967 levels above an ERC of 70.0 would be maintained for a continual 26 days, with a maximum high value reached on August 31st (80.0). The 1988 season never matched 1967 in ERC heights, but continued a steady climb upward until reaching the 1988 maximum high value of 71.0 on September 5th. A cold front passage on September 6, 1988 would prevent the ERC levels from increasing any further. Both the 1967 and 1988 seasons exceeded the 1973-1987 100th percentile levels of an ERC of 60.0.

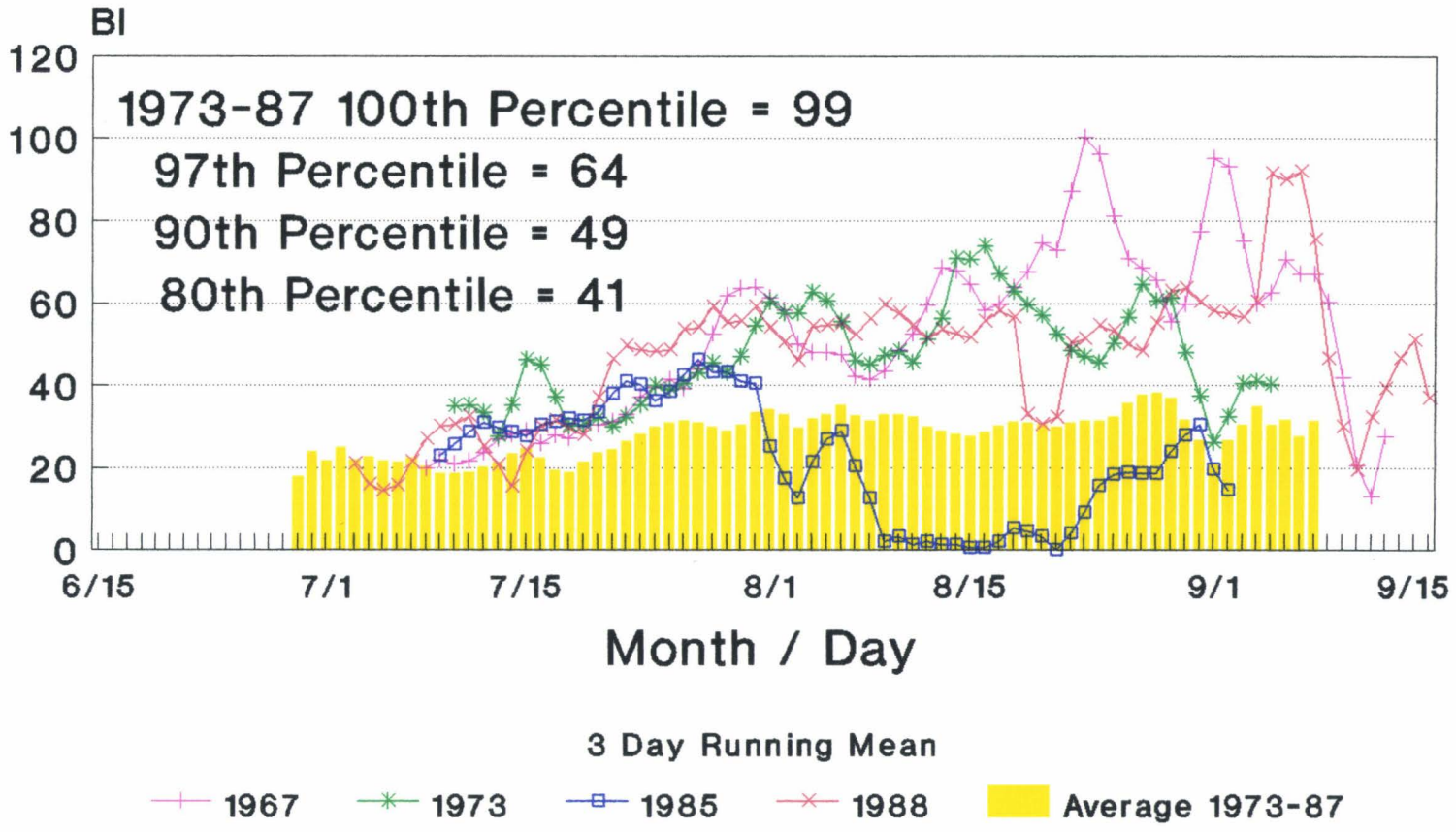
Burning Index

The seasonal average BI at the Spotted Bear Lookout, like the ERC index, shows a minimal amount of seasonal variability with a maximum average change of less than 21 points (Figure B-8). While it is difficult to declare the seasonal average BI distribution bimodal because of the slight difference in summer values, there are two peaks achieved on August 6th (35.3) and again on August 28th (38.2).

All 4 severe fire danger seasons can be seen to have cleanly climbed above the seasonal average BI values by July 16th. Each season steadily climbs away from the average BI, with the 1988 season initially showing a greater rate of deviation from the average. The 1967, 1973, and 1985 seasons from mid to late July are very similar in their BI levels. The 1988 season proved to be the earliest to move above the 80th percentile level (45.0) on July 21st (46.3). The 1988 season was followed in quick succession by 1985 on July 27th, 1967 on July 28th, and 1973 on July 30th. The 1985 season continued to climb until July 27th when a maximum high BI value of 46.3 was reached, after which the season ending decline commenced. The remaining three severe seasons continue to climb until late July - early August at which time each season tends to fluctuate around values between the 80th and 97th percentile (BI of 64) levels for the first ten day period of August. The 1967 and 1973 seasons rapidly climbed above the 97th percentile level by August 14th in 1973, and on August 18th in 1967. The maximum high BI value for 1973 would be attained on August 16th (74.0). The maximum high BI for the 1967 season would arrive on August 23rd (100.3), followed by a decline in BI then a rapid rebound to a second peak on September 1st (95.3) and the eventual season ending decline. The 1988 BI late season values and trends at this station is considerably different than what occurred during either the 1967 or 1973 seasons. Except for a short three day period when the 1988 BI dropped back to near average, the 1988 season stayed relatively level between BI values of 50 and 60. It would take increased winds on September 5-7 in 1988 to significantly change the BI level

Figure B-8. Burning Index for the Spotted Bear Lookout NFDRS Station, Flathead National Forest; Seasonal Average 1973-1987, 1967, 1973, 1985, and 1988 severe fire danger seasons.

Burning Index
Spotted Bear Lookout (240213)



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at the lookout. The 1988 maximum high BI value of 92.0 would be achieved on September 7th after which the BI plummeted back to seasonal average levels.

Thousand Hour Fuel Moisture

Early July Thousand Hour Fuel Moisture values of 24% are the seasonal average maximum high values, and are followed by a steady decline (Figure B-9). The seasonal average maximum low moisture level is reached on August 7th (17.1%) after a rate of decline in moisture of -0.3% per day. A slight rebound in moisture occurs following the maximum low until a small peak moisture value is achieved on August 16th (18.7%) after which the moisture level remains relatively steady until declining slightly in early September.

While the 1988 severe fire danger season is the first of the four seasons documented to move below the seasonal average Thousand Hour Fuel Moisture level on July 7th, all began their decline below the seasonal average within four days of each other. All four seasons also had a very similar rate of moisture loss during the last half of July, approximately -0.2% per day. The 1985 season was the first fire season to reach the maximum low moisture content, 14% on July 29th. This level was maintained that season for 3 days before a rapid (+1.0% per day) return to the seasonal average occurred, followed by an even more rapid (+1.9% per day) climb well above normal for August. The remaining three severe seasons remained at the same approximate moisture levels until August 5th at which point the 1973 season stabilized at 13%. The 1967 and 1988 seasons would still continue to decline slightly with 1988 stabilizing at 12% on August 11th, and the 1967 season doing the same on August 18th at 9%. The 1988 season would reach a maximum low moisture content of 10% on September 3rd and maintained that level for 6 days before starting to recover. The 1967 season would reach a maximum low moisture content of 7.6% on September 4th and not begin recovery until after three days. These 7.6% readings were the lowest Thousand Hour Fuel Moisture readings for any of the severe fire seasons and stations documented for the Glacier National Park and Bob Marshall Wilderness complex (Bushey 1990). The 1967 season maintained 25 days with a moisture levels of 9% or less from mid-August until mid-September. This extended period of 9% or less moisture content was also the longest period of extreme drought measured from the stations. Both the 1967 and 1988 seasons started their moisture content recovery at approximately the same date, and much later than the other severe seasons evaluated.

SPOTTED BEAR RANGER STATION, FLATHEAD NATIONAL FOREST

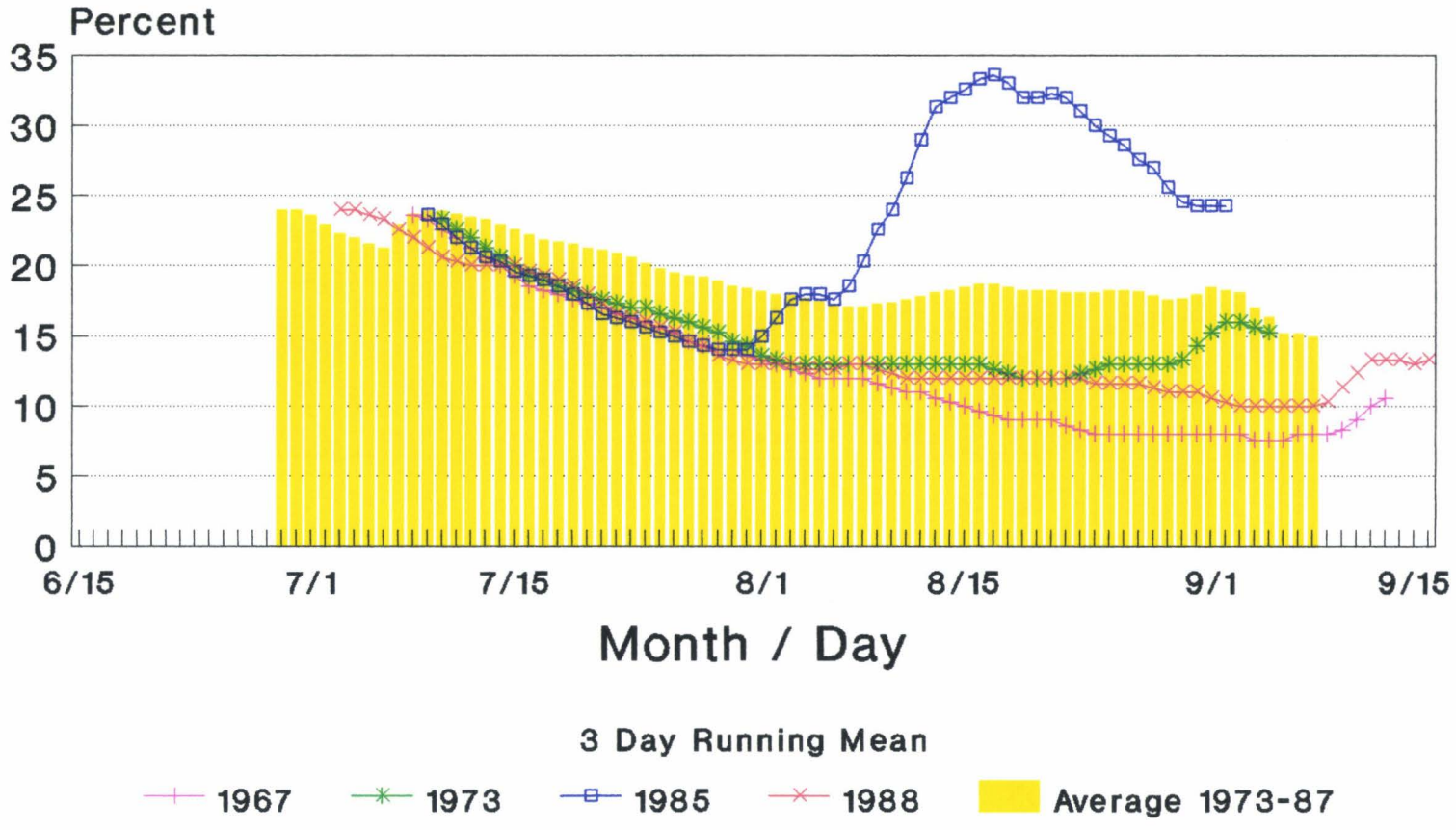
Spotted Bear Ranger Station is the low elevation companion NFDRS station to the Spotted Bear Lookout. This station is about 4 miles northwest of the lookout and is at an elevation of 3,725 ft msl, or 3,475 ft lower than the lookout. Spotted Bear Ranger Station is approximately 44 miles north-northwest of the Scapegoat Wilderness portion of the Bob Marshall Wilderness complex.

Energy Release Component

The seasonal average ERC begins the season with a maximum low ERC value of 4.3 on May 30th (Figure B-10). From this point in time the ERC level at this station climbs rapidly at first, then more gradually in July until achieving the first peak of a bimodal peak distribution. This first peak occurs on August 1st (32.0), followed by an undulating decline into late September. The second peak is found during the first half of October and occurs after a rapid

Figure B-9. Thousand Hour Fuel Moisture for the Spotted Bear Lookout NFDRS Station, Flathead National Forest; Seasonal Average 1973-1987, 1967, 1973, 1985, and 1988 severe fire danger seasons.

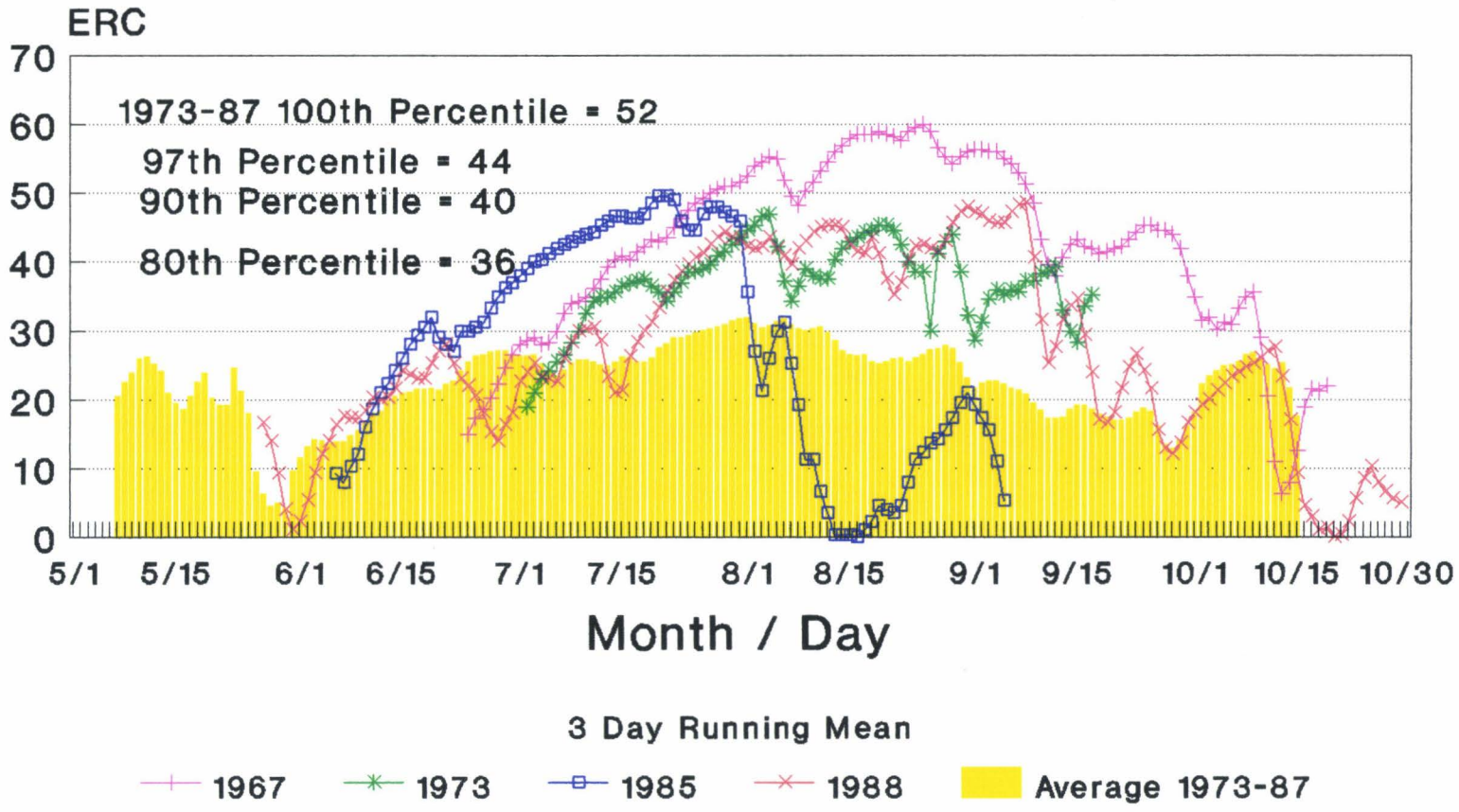
Thousand Hour Moisture
Spotted Bear Lookout (240213)



C. Bushey/MPFS

Figure B-10. Energy Release Component for the Spotted Bear Ranger Station, Flathead National Forest; Seasonal Average 1973-1987, 1967, 1973, 1985, and 1988 severe fire danger seasons.

Energy Release Component
Spotted Bear Ranger Station (240214)



C. Bushey/MPFS

rise to 26.8 on October 9th. The 80th percentile calculated from the 1973-1987 seasonal data is 36, while 40 marks the 90th percentile level.

Both the 1985 and 1988 severe fire danger seasons initially climbed above the seasonal average by June 11th. However, while the 1985 season would continue to rapidly climb above the seasonal average the 1988 season tumbled back below the average for an extended period of time. 1985 would pass the 80th percentile level on June 29 (36.3). The next season to move above the seasonal average was 1967 which occurred on June 30th, and which continued climbing in a steady manner. July 5th would be the date the 1973 season moved above the seasonal average and also continued to move upward at a steady rate. It wouldn't be until July 17th that the 1988 season at this station would finally recover enough to again sustain a climb above the 1973-1987 average ERC level. The 1985 season would reach the season's maximum high ERC value on July 20-21 (49.6) before beginning to collapse under persistent rains. No other severe season examined achieved the 80th through 97th percentile levels (June 29 and July 10) as rapidly as the 1985 season. It would take until July 11th (36.3) for 1967, July 15th (36.6) for 1973, and July 21st (36.0) for 1988 to attain the 80th percentile level. The 1973 season would reach it's maximum high ERC on August 4th (47.0), and while the season stayed at ERC levels generally above the 80th percentile through early September it never again surpassed the August 4th value. A steady climb to heights above the 1973-1987 100th percentile level marked the 1967 season. This season reached its maximum high ERC on August 25th (60.0), dropped slightly for another 10 days, then started to decline to the 90th percentile on September 5th. Between September 13th and 29th the ERC level stayed between the 90th and 100th percentile levels, then began it's season ending decline. 1967 would record 47 days at or above the 97th percentile level of the 1973-1987 seasons, and 31 days above the 100th percentile for this station. The late-summer 1988 season seldom approached 1967 in ERC fire danger severity. While the 1967 season was at ERC levels above the 100th percentile, the 1988 ERC index values were consistently between the 90th and 100th percentiles. A maximum high 1988 ERC level of 48.6 would be achieved on September 8th, followed by a precipitous decline. There would be 16 days during 1988 that would equal or exceed the 97th percentile, none over the 100th percentile level. By September 11th the 1988 season had returned to the seasonal average ERC levels and except for a brief period would remain below that level. It would take the 1967 season until October 11th before the ERC level dropped back below the seasonal average.

Burning Index

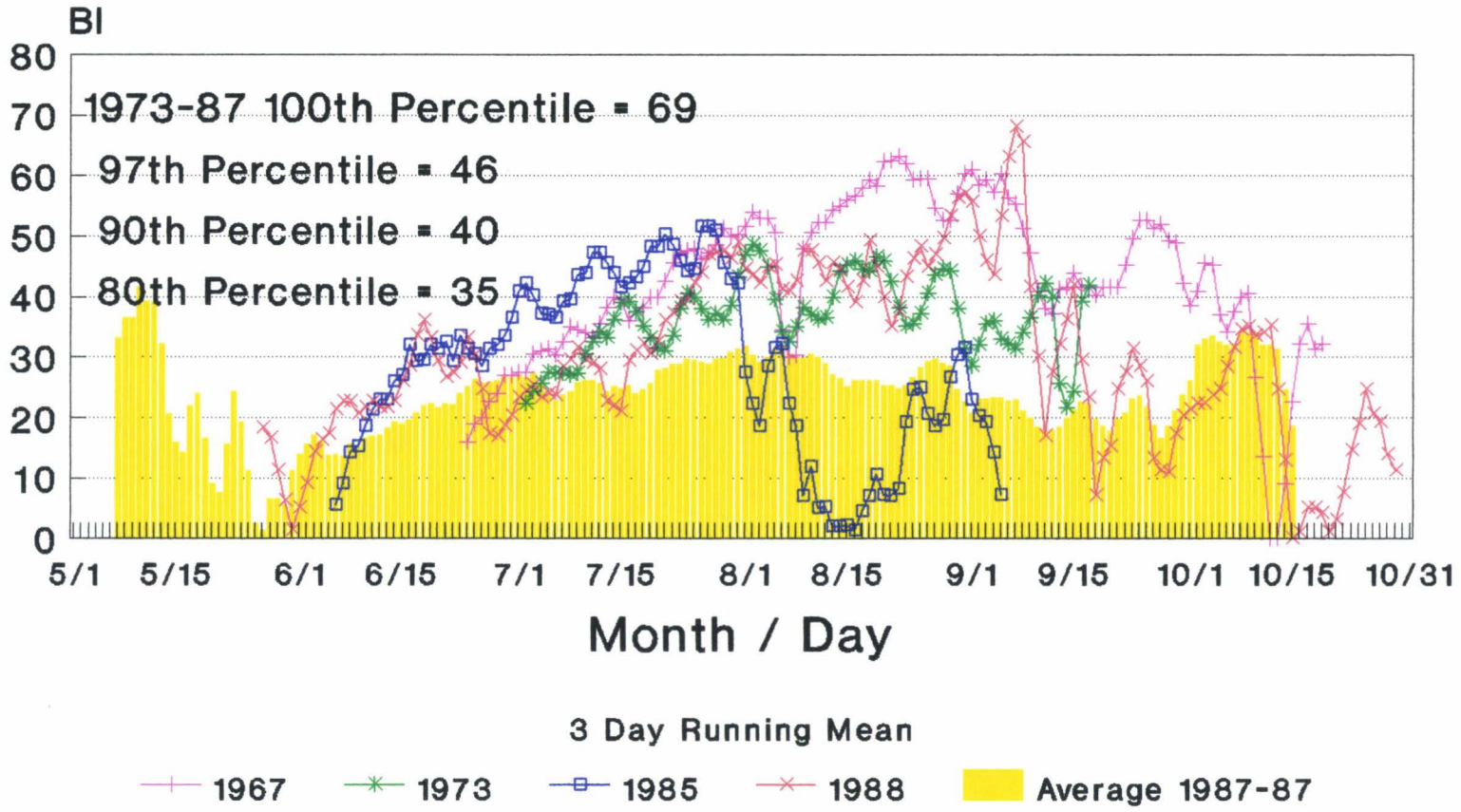
The seasonal average BI at the Spotted Bear Ranger Station reaches a maximum low on May 21st (Figure B-11). A summer seasonal average peak is reached on August 1st (31.8) after a steady two month climb. Following the summer BI peak there is a similar two month decline in BI with occasional small peaks around the last ten day period of August, and during the second and third ten day periods of September. beginning at the end of September there is a rapid increase in BI measured fire danger which reaches a late season peak of 33.5 on October 4th. The 80th percentile level for BI at this station from the 1973-1987 years was 35, while the 90th percentile level rose to 40.

The overall pattern of the development of the individual severe fire danger years as measured by BI is very similar to the previously discussed pattern for ERC. The BI usually took from one to two extra days to climb above the seasonal average than did the ERC values. 1988 was the earliest of the four seasons to reach the 80th percentile with a brief rise to 36.0 on June 18th.

Figure B-11. Burning Index for the Spotted Bear Ranger Station, Flathead National Forest; Seasonal Average 1973-1987, 1967, 1973, 1985, and 1988 severe fire danger seasons.

Burning Index

Spotted Bear Ranger Station (240214)



C. Bushey/MPFS

The 1985 season during this early seasonal period very closely matches the rise of 1988. 1985 would not attain the 80th percentile level until June 30th (36.6) and after this point in time would climb faster than the 1988 season which fell back to below the seasonal average. 1985 would pass the 90th percentile level on July 1st (41.0), and the 97th percentile on July 11th (47.3). Maximum high BI levels of 51.6 would be reached on July 26-27, 1985, followed shortly by the season's dramatic collapse. It would take 1967 until July 22 (45.6) to reach the 90th percentile, and only the next day to achieve the 97th (47.3). After recovering from the late June tumble back below the seasonal average, the 1988 season regained its momentum and again gained the 80th percentile level on July 21st (36.0) and rapidly rose to the 90th on July 25th (42.3), and then the 97th on July 27th (47.0). The 1988 season would fluctuate mostly between the 90th to slightly above the 97th percentile levels until late August. The 1973 season after an undulating climb finally reached the 90th percentile on July 31st (43.3), and after a brief period back below the 80th percentile level would finally climb up to the 97th percentile on August 1st (47.0). The next day would see the 1973 maximum high BI level reached (48.6). After attaining this level the 1973 season would fluctuate between the 80th percentile to just below the 97th percentile until September 12th. A maximum high BI would be set on August 22nd in 1967 (63.3). The 1967 season would eventually have 46 days above the 97th percentile level; most of late July, all of August, and early September. A maximum high BI would finally be reached during 1988 on September 7th (68.0), just below the 100th percentile level. 1988 BI levels would begin to drop on September 8th, and would end up with 21 days above the 97th percentile level. Only the 1967 and 1988 seasons of the four examined continued with average to above average BI values into late September and October. Of the two seasons, 1967 had the greatest fire danger rating at this station, staying above the 80th percentile level until October 6th.

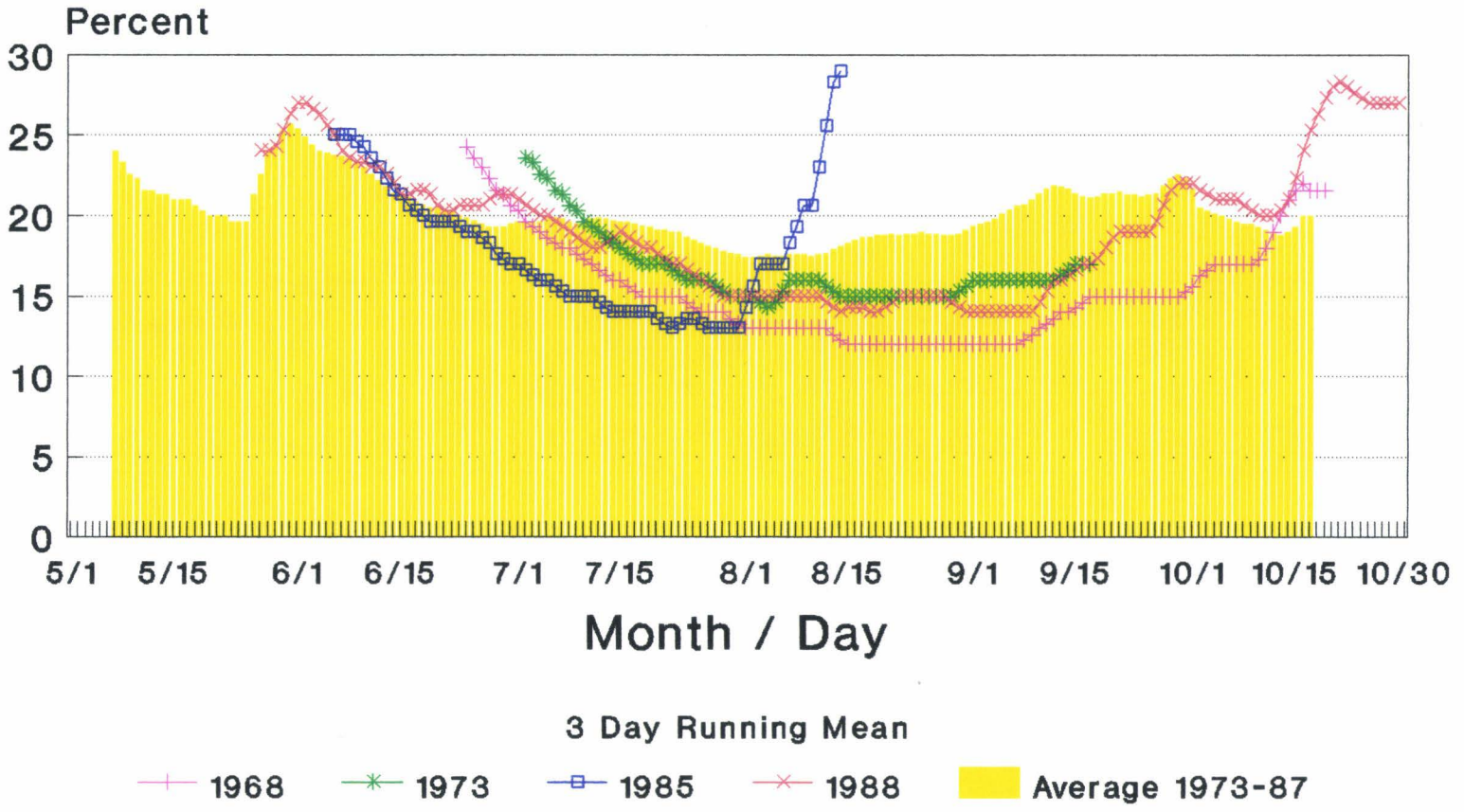
Thousand Hour Fuel Moisture

The high seasonal average Thousand Hour Fuel Moisture occurs on May 31st (25.7%) before entering into the fire season period of declining moisture (Figure B-12). A decline (-0.2% per day) in moisture occurs until June 29th, after which there is approximately half of a month of a slight increase in moisture content. A gradual decline (-0.1%) of moisture continues until a seasonal average maximum low value of 17.4% is attained on August 2nd. After this low value there is an increase in moisture (+0.3% per day) until the later part of August when a plateau is reached of about 18.9%. beginning on August 31st moisture levels again increase (+0.2% per day) until an end of the season maximum high moisture level of 21.9% is reached on September 12th. These high moisture levels are maintained until October at which time a period of drying evidently occurs, again lowering the moisture content temporarily before the arrival of snow.

Of the four severe fire danger seasons investigated the 1985 season at this station was the first to start to move below the season average Thousand Hour Fuel Moisture level (June 17th, 20.3%). The 1988 early season moisture levels ranged slightly above the seasonal average, both the 1967 and 1973 seasons declined from levels much higher than the average. 1967 would move below the average on July 3rd (19.3%) at an initial steep decline (-0.4% per day). The 1988 season is the next in chronological order to move below the average on July 6th (19.6%) and dropped at an approximate rate of -0.2% per day. The 1973 season waited until July 11th (19.3%) before the seasonal average boundary was

Figure B-12. Thousand Hour Fuel Moisture for the Spotted Bear Ranger Station, Flathead National Forest; Seasonal Average 1973-1987, 1967, 1973, 1985, and 1988 severe fire danger seasons.

Thousand Hour Moisture
Spotted Bear Ranger Station (240214)



C. Bushey/MPFS

crossed, with Thousand Hour Fuel Moisture levels dropping at a rate also about -0.2% per day. After declining at rates similar to the 1973 and 1988 seasons, the 1985 season reached a maximum low moisture level of 13% on July 22nd. There would be a total of six days at this level during 1985 before levels again began to rebound on August 1st at a rapid rate of +1.1% per day. In 1973 the maximum low moisture content would be briefly attained on August 4th (14.3%) and then after a brief fluctuation the level would stabilize at 15.0% for the last half of August. During the 1967 season the maximum low moisture level was reached on August 12th at 12%, and was maintained at that same level for 24 days. The 1967 season recovered slowly at a rate of about +0.2% per day. 1988 would experience three periods when the maximum low moisture content of 14.0% was reached. The first period in 1988 began on August 14th for the single day, again on August 18th for two days, and the last period began on August 31st and lasted for ten days through September 9th. Moisture recovery in 1988 occurred at a rate of +0.3% per day.

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APPENDIX C - RED BENCH FIRE; FIRE BEHAVIOR, FIRE WEATHER CHRONOLOGY

August 17 (Julian Date 230)

Cyclone Peak Lookout (Mary Peterson) records showed heavy lightning activity between 2100 and 2400 hrs. At 2300 hrs the observer logged a ground strike at Azimuth Reading 305'02 degrees, section 19, T37N, R23W. A compass line from the lookout at 305'02 runs precisely through the origin of the Red Bench Fire. Inaccuracy in recording distance is a common occurrence due to the darkness and the deceiving appearence that often accompanies lightning strikes (Hurd 1988).

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	86F	24%	5	0.00	113%	103%	5%	6%	15%	17%	35	37
W. Glacier	86F	31%	6	0.00	128%	88%	6%	9%	14%	15%	39	42
S. Bear LO	71F	25%	12	0.00	82%	61%	5%	6%	10%	12%	55	71
S. Bear RS	86F	19%	5	0.00	105%	73%	5%	8%	14%	14%	42	45
H.Horse RS	82F	28%	6	0.00	98%	50%	5%	7%	12%	13%	48	52

2300 hrs. 305'02 degrees 19/37N/23W Masonry Peak area (Cyclone LO Lightning Strike Record)

This lightning strike would later be determined to be the cause of the Red Bench Fire on the Flathead National Forest and Glacier National Park. The Red Bench Fire would erupt in to known existance during the afternoon of September 6th, after lying dormant in a smoldering condition for nineteen and 1/2 days. It was determined during the wildland arson investigation following discovery of the fire, that there were numerous reasons to list the fire as a lightning holdover.

-- Reasons for the Holdover Conclusion --

1) lightning strike on a north facing slope;
2) only a few hours of direct sunlight in the area of the strike each day;
3) fuel and ground litter conducive to a creeping holdover fire;
4) aspect allowed for retention of moisture;
5) Glacier National Park had a holdover lightning strike from the same storm (August 17th) surface on September 1st (the Square Fire), fifteen days after the strike and only four 1/2 days prior to the Red Bench Fire;
6) several people smelled "fresh" smoke on separate occasions during the week preceding the fire;
7) Cyclone Peak Lookout recorded a strike on the same heading as the fire origin was later determined to be;
8) no logging activity near where the fire started;
9) aerial photography shows area of origin on a steep slope in an area which would preclude human activity;
10) general topography in the area of origin provided protection from general west to southwest winds in the vicinity (even the initial

crowning activity did not appear to be wind influenced)(Hurd 1988).

Regional Weather: Hot, dry air mass remained over the Region with a light wind flow pattern. Another mostly, dry Pacific weather system was slowly approaching from the west and was expected in the Region by the evening of the 18th or shortly thereafter. Skies were mostly clear across the Region during the night and morning hours with no precipitation reported. An easterly flow continued across the area with winds generally light and less than 10 MPH overnight. Great Falls and Billings occasionally ranged from 15 to 20 MPH. Low morning temperatures were in the mid-30's in the southwest to the high 50's in the southcentral and east. West Yellowstone was the coolest location at 33 degrees, Billings and Miles City the warmest at 59. Slight temperature inversions occurred across the Region during the night and morning. Strong high elevation winds at 0600 hrs were recorded at Boise with 20 to 25 MPH winds at the 5000' - 9000' levels, and at Spokane where 20 - 30 MPH winds occurred between 5000' - 9000' and 35 - 45 MPH speeds above 9000'. During the afternoon the surface high pressure maintained the easterly light wind flow. By noon smoke had reduced visibility to 1/2 mile at West Yellowstone. Afternoon temperatures were in the 80's and low 90's, and ranged from 81 at Grangeville and 83 at Cutbank to 98 at Thompson Falls (Bushey 1989).

August 18 (Julian Date 231)

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	74F	30%	9	0.00	123%	98%	5%	6%	13%	16%	37	52
W. Glacier	77F	29%	12	0.02	115%	89%	6%	10%	15%	15%	37	52
S. Bear LO	58F	40%	7	T	83%	62%	6%	6%	11%	12%	44	51
S. Bear RS	72F	31%	8	0.00	104%	72%	5%	7%	13%	14%	23	21
H.Horse RS	75F	19%	30	0.00	95%	47%	4%	6%	11%	13%	52	119

Regional Weather: Skies were mostly clear across the Region during the night except along the Idaho / Montana border where some mostly dry thunderstorms were reported. Most of the lightning during the night was concentrated in this area and on the Idaho Panhandle, Flathead, Kootenai, and Lolo National Forests. A total of 200 strikes were recorded during the 24 hour period (there would be discovered a 50 - 60% ignition rate from these strikes). Winds at Missoula and Glasgow were gusting to 20 to 30 MPH after midnight, with most locations reporting speeds of 15 MPH or less. Just before dawn Glasgow was still reporting winds 25 to 30 MPH. Overnight low temperatures were mostly in the 50's and 60's and ranged from 33 at West Yellowstone to 65 at Miles City. The NWS raised Red Flags in western Montana and northern Idaho during the morning for an expected combination of strong, gusty winds, warm temperatures, and low humidities associated with a frontal passage. Red Flags were also raised in eastern Montana for dry thunderstorms, very low humidities, and hot temperatures. By the late afternoon temperatures had warmed into the 80's to high 90's, ranging from 76 in Grangeville (78 in Cutbank) to 99 at Billings. The frontal system had moved east of the divide and was on a Malta to Lewistown to Big Timber line by 1400 hrs. By 1630 hrs the front was extended from Billings to Yellowstone National Park. Strong thunderstorms moved across northeastern Montana between 2000 and 2200 hrs with strong associated winds.

Glasgow reported 70 MPH thunderstorm wind gusts. Glasgow also reported .25" of rain and Broadus .02" (Bushey 1989).

Long-Range Weather Forecast: Three to five day outlook was for warm and dry with a chance of some thunderstorm activity. Six to ten day outlook indicated above normal temperatures and below normal precipitation (Bushey 1989).

August 19 (Julian Date 232)

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	74F	33%	5	0.00	124%	98%	6%	8%	13%	16%	37	37
W. Glacier	75F	27%	10	0.00	113%	88%	5%	9%	14%	15%	38	50
S. Bear LO	No Data											
S. Bear RS	No Data											
H.Horse RS	No Data											

Regional Weather: During the early morning hours winds returned to 15 MPH or less across the Region after the thunderstorms of the late hours of the previous day. Lighting strikes totaled 4,394 and were confined to areas within the eastern third of Montana and into North Dakota. Skies were clear to partly cloudy except along the North Dakota border through the night. Overnight low temperatures ranged from the high 30's in the southwest to the mid-60's in the east. Drummond had the coolest temperature 35 degrees, Miles City was the warmest at 64. The cool, calm conditions in the western, and central portions of the Region contributed to the creation of morning temperature inversion layers with extensive areas of trapped smoke. Weak high pressure brought sunny afternoon skies with light winds, and drier air. Winds were mostly 5 to 15 MPH, and again visibility was reduced by smoke across the southwestern portion of the Region. Afternoon temperatures were mostly in the 80's, and ranged from 82 at West Yellowstone to 89 at Dillon and Great Falls. Late in the evening a dry cold front moved down from British Columbia creating some thunderstorms along the front with slightly cooler air behind it (Bushey 1989).

Long-Range Weather Forecast: Three to five day outlook called for slightly cooler temperatures initially, then warming with widely scattered thunderstorms. The six to ten day outlook was for temperatures to be above normal with little or no rainfall. Normal temperatures for this time period are in the 70's to mid-80's range (Bushey 1989).

August 20 (Julian Date 233)

Cyclone Lookout daily diary records show .23" of rain and lightning on this date (Hurd 1988).

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	63F	62%	4	0.08	125%	99%	12%	21%	15%	17%	27	27
W. Glacier	55F	88%	0	0.01	114%	89%	19%	14%	15%	15%	0	0
S. Bear LO	62F	25%	2	0.00	83%	61%	5%	6%	11%	12%	55	46
S. Bear RS	79F	18%	8	0.00	105%	72%	4%	7%	13%	14%	44	54
H.Horse RS	75F	27%	10	0.00	95%	47%	4%	6%	12%	13%	50	64

Regional Weather: Skies were mostly clear across the Region during the night except for the line of thunderstorms along the Canadian dry cold front which was temporarily hung up. Only traces of moisture had been reported. Skies remained smokey from the forest fires and winds were generally light at most locations. Glasgow was reporting since midnight 15 to 25 MPH gusts. Low overnight temperatures ranged from 38 at Butte to 63 at Miles City and Broadus. In the morning the NWS issued Red Flag Warnings in northcentral Idaho and westcentral Montana for extremely low humidities and dry lightning in the mountains; and in eastcentral Montana for late afternoon and evening strong thunderstorms, strong winds, and poor humidity recovery. During the afternoon clouds from the weather system centered in southern Alberta were creating widely scattered showers in the northwest quarter of the Region, mostly over Kalispell and Glacier National Park. Hail was reported at Kalispell at noon. Elsewhere skies were partly cloudy. The leading cold front was in central Montana by 1100 hrs and was producing gusty west to northwest winds of 15 to 30 MPH. Front started to affect the Yellowstone area early in the afternoon. Northwest gusts reached 44 MPH at Cutbank and 35 MPH at Great Falls and Livingston, and average from 20 to 30 MPH in Yellowstone National Park with gusts to 40 MPH, higher peaks had 60 to 70 MPH winds. By 1500 hrs the front was on a line from Malta-Lewistown-Big Timber to just northwest of West Yellowstone and was gaining strength and speed. Afternoon temperatures ranged from the upper 50's and low 60's in the northwest to the 90's in the southeast. Broadus was the warmest location at 103 degrees (Bushey 1989).

Long-Range Weather Forecast: Three to five day forecast called for fair and mild at first, then warming on the 23rd and 24th. Widely scattered showers and thunderstorms in eastern areas. The six to ten day outlook was for above normal temperatures and below normal precipitation. Normal high temperatures are typically in the 70's to mid-80's range at this time of the season (Bushey 1989).

Miscellaneous: The long term Palmer Drought Severity Index remained essentially unchanged from earlier maps as abnormal dryness continued to cover most of the Region (Bushey 1989).

August 21 (Julian Date 234)

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	66F	51%	5	0.02	126%	99%	8%	8%	15%	17%	33	34
W. Glacier	67F	48%	12	0.13	117%	91%	8%	8%	16%	16%	35	49
S. Bear LO	51F	46%	6	0.02	86%	63%	8%	7%	14%	12%	47	47
S. Bear RS	67F	33%	5	0.18	110%	76%	8%	18%	16%	15%	33	36
H.Horse RS	66F	43%	8	0.24	99%	50%	8%	15%	14%	14%	39	47

Regional Weather: Skies overnight across the Region during the morning hours were fair to partly cloudy except for a northeast-southwest line of showers through central Montana. Only isolated lightning had occurred during the previous 24 hours with a total of 433 strikes most of which were on the Idaho Panhandle, Kootenai, and Flathead National Forests during yesterday afternoon. A narrow band of strikes occurred south of the Yellowstone area and across eastern Montana and into North Dakota as the front passed through that area. Winds were mostly light and less than 15 MPH. Overnight temperatures were in the 40's and 50's, and ranged from 35 at Drummond to 59 at Broadus. By late afternoon western portions of the Region were clear as a high pressure ridge moved into the Region from the Pacific, and east of the continental divide skies were partly cloudy in the north and sunny in the south. A Red Flag was issued in the afternoon for strong winds along the Canadian border in eastern Montana associated with an upper level disturbance. Northeast Montana reported the strongest winds with Glasgow reporting gusts from 30 to 40 MPH. Afternoon temperatures were in the upper 70's and 80's, ranging from 72 at West Yellowstone to 83 at Thompson Falls (Bushey 1989).

August 22 (Julian Date 235)

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	74F	16%	4	0.00	123%	96%	6%	14%	16%	16%	34	35
W. Glacier	74F	29%	6	0.00	117%	91%	6%	14%	16%	16%	34	38
S. Bear LO	No Data											
S. Bear RS	No Data											
H.Horse RS	No Data											

Regional Weather: Building high pressure was expected to continue for another 2-3 days with warming temperatures and very low humidities. Skies were clear through the night, winds died down and were less than 15 MPH. The northern lights were visible at several stations during the very early morning hours. Overnight temperatures were in the 40's and 50's, ranging from 25 at West Yellowstone to 54 at Miles City. Temperatures cooled into the 30's at most locations over 5,000' and humidity recovery was much improved except for southwestern Montana and the east slopes of the Rockies were it remained dry. Lightning activity during the past 24 hours was restricted to 148 strikes in northcentral Wyoming. High pressure at the surface and aloft were building.

High clouds covered the northeast portion of the Region during the afternoon while everyone else enjoyed sunny skies. West to northwest winds were gusting to 25 MPH in many areas. Afternoon temperatures were in the 70's and 80's, ranging from 75 at Lewistown to 89 at Thompson Falls. In Yellowstone National Park, Tower Falls recorded an afternoon low relative humidity of 6% which would be the lowest humidity reading in the Park during the year (Bushey 1989).

Miscellaneous: A subsidence inversion dropping below 9000 ft was noted by the RICO fire Behavior Service Center (Bushey 1989).

August 23 (Julian Date 236)

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	78F	33%	4	0.00	124%	97%	7%	15%	14%	16%	33	33
W. Glacier	81F	29%	8	0.00	117%	91%	5%	10%	15%	16%	36	44
S. Bear LO	65F	35%	6	0.00	83%	59%	5%	5%	11%	12%	55	55
S. Bear RS	83F	19%	3	0.00	110%	75%	4%	8%	15%	15%	41	40
H.Horse RS	77F	13%	11	0.00	100%	50%	4%	10%	14%	14%	45	64

Regional Weather: Strong upper ridge of high pressure over the western states continued to hold the storm track to the north over Canada. Skies were clear during the night across the Region, winds were light and less than 15 MPH. The subsidence inversion contributing to drying fuel conditions at the higher elevations dropped to between 5,000 - 6,000 ft in elevation during the night. Later that morning the inversion rose to the 8,000 ft level. High pressure was rebuilding. Overnight temperatures were in the 40's and 50's, ranging from 26 degrees at West Yellowstone to 55 at Miles City. Afternoon winds across the Region were generally light except for the northwest corner where breezes of 10 to 20 MPH were reported. The light winds failed to blow out the smoke from the fires burning in Yellowstone National Park and visibility was reduced to less than a mile at West Yellowstone. Afternoon temperatures reached into the 80's and 90's, ranging from 79 at Libby to 100 degrees at Thompson Falls (Bushey 1989).

Long-Range Weather Forecast: Three to five day forecast was for hot and dry with isolated thunderstorms in the southern zones near the mountains and slight cooling to the north. The six to ten day outlook indicated above normal temperatures and below normal precipitation. Normal temperatures are in the 70's to mid-80's range (Bushey 1989).

August 24 (Julian Date 237)

Clarence R. "Bud" Anderburg, Sale Administrator for the Red Bench Timber Sale, smelled smoke in the vicinity of the fire origin during a routine timber sale inspection. He felt the smoke was different than the general drift smoke in the area caused by the Dry Fork Fire on the Kootenai National Forest. He stated a storm came throught the Red Meadow area on the 20th which produced heavy rain and lightning. The upper Coal Creek drainage and Red Meadow drainage are noted for getting rain or snow everytime a cloud bank comes through (Hurd 1988).

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	88F	21%	5	0.00	121%	93%	4%	6%	14%	16%	39	41
W. Glacier	87F	27%	6	0.00	117%	91%	5%	9%	15%	16%	37	41
S. Bear LO	78F	30%	3	0.00	81%	57%	4%	4%	9%	12%	59	51
S. Bear RS	92F	14%	8	0.00	109%	74%	3%	6%	14%	15%	43	54
H.Horse RS	85F	18%	7	0.00	100%	50%	4%	10%	13%	14%	45	53

Regional Weather: As the strong high pressure continued skies were again clear during the night across the Region. Winds were variable and less than 15 MPH. Temperatures last night fell into the 40's and 50's, ranging from 31 at West Yellowstone to 56 at Miles City. The subsidence inversion over the Northern Rocky Mountains lifted during the night to the 14,000 ft level, then dropped to between 10,000 - 12,000 ft level later that morning. During the morning a Red Flag Warning was issued for eastern Montana for very low afternoon and evening humidities below 15%. Clear skies continued to dominate the Region during the afternoon, except where heavy smoke reduced visibilities to less than 1/2 mile in the southwestern portion of the Region. Winds remained variable at 10 MPH or less. Temperatures warmed into the 80's and 90's, ranging from 88 at West Yellowstone to 105 at Thompson Falls. Most stations were in the mid to high 90's. To date, Missoula had received only .29" of rainfall during the month of August, normal for the month was .95". In the last 40 days this station had reported only 3 days with moisture (Bushey 1989).

Long Range Weather Forecast: Three to five day outlook was for dry and warm with scattered late afternoon and evening thunderstorms. The six to ten day outlook predicted above normal temperatures and below normal precipitation. Normal high tmperatures for this time period are usually in the 70's to low 80's range (Bushey 1989).

August 25 (Julian Date 238)

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	83F	29%	2	0.00	116%	90%	5%	8%	15%	16%	38	52
W. Glacier	55F	87%	11	0.00	116%	90%	5%	8%	15%	16%	38	52
S. Bear LO	72F	23%	6	0.00	78%	54%	4%	4%	8%	11%	62	60
S. Bear RS	91F	13%	5	0.00	108%	74%	3%	6%	13%	15%	44	47
H.Horse RS	82F	25%	2	0.00	99%	49%	5%	8%	12%	14%	47	42

Regional Weather: Skies remained clear during the night, winds at most stations were less than 15 MPH. Billings and Miles City were the exceptions, reporting winds from the north and northeast at 10 to 20 MPH. Low temperatures in the morning were mostly in the 50's, ranging from 36 at West Yellowstone to 58 at Billings and Miles City. NWS issued a Red Flag Warning for all of northern Idaho and western Montana for dry lightning, dry fuels, and low humidities. During the morning a small disturbance did sneak in under the dome

of high pressure and produced mostly dry lightning from about Missoula northward. A few light showers, mostly just sprinkles, were scattered in areas west of the continental divide. This activity moved east during the afternoon. The largest cell crossed across the Nez Perce and Clearwater National Forests, then crossed the Bitterroot Valley south of Missoula. Considerable lightning and strong gusty winds occurred with this thunderstorm. The cell stalled over the Bitterroot and Deerlodge National Forests and later dispersed during the late morning. At 0600 hrs the subsidence inversion that had been over the Region for several days was approximately at the 12,000 - 13,000 ft elevation between Spokane and Great Falls and had little effect on the fires. By evening partly cloudy skies were across the Region. Eleven out of 18 reporting station from across Montana were reporting smokey skies, Hamilton had 6/10's of the sky covered by smoke and was about the worst. High temperatures ranged from 82 at Glasgow and Miles City to 97 at Thompson Falls (Bushey 1989).

Long Range Weather Forecast: Three to five day forecast was for near normal temperatures in northern Idaho and western Montana and for above normal temperatures east of the divide. Precipitation was expected to be near normal west of the divide and dry to the east. Normal high temperatures for this time period are inthe 70's to low 80's (Bushey 1989).

August 26 (Julian Date 239)

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	60F	79%	2	0.12	121%	93%	17%	23%	15%	16%	25	23
W. Glacier	65F	63%	10	0.00	116%	89%	11%	10%	15%	16%	34	43
S. Bear LO	53F	78%	8	0.03	81%	56%	12%	7%	10%	12%	50	51
S. Bear RS	68F	45%	7	T	110%	75%	7%	5%	14%	15%	41	45
H.Horse RS	66F	51%	30	0.00	97%	48%	10%	9%	12%	13%	45	95

Regional Weather: Skies were mostly clear over the western portion of the Region, and mostly cloudy in the east. Smokey conditions still continued over much of western Montana. Thunderstorms developed over the southeastern corner of the Region with precipitation limited to trace amounts. Scattered lightning was being recorded with 50 discharges between 0600 and 0930 hrs. Overnight low temperatures ranged from 45 at West Yellowstone to 60 degrees at Glasgow. During the afternoon a fast moving Canadian cold front moved through the Region bringing variable cloudiness, some light showers, gusty winds, and cooler temperatures. Wind speeds of 25 to 30 MPH were reported at several locations with a few gusts to 40 MPH. Afternoon winds over Yellowstone National Park were generally west to northwest and were gusting to 35 MPH until 1800 hrs then shifted to the northeast and became light in speed. Low level flow east of the divide in Montana was more northerly. Rainshowers fell at several locations with Great Falls reporting the greatest official amount of .16". Other unofficial stations in the northcentral portion of the Region recorded .57" at Belly river and 2.2" at St. Mary's. Afternoon temperatures ranged from the mid-50's behind the front to the mid-80's ahead of it. Extremes at 1500 hrs were a cool 56 at Great Falls to a warm 86 degrees at Miles City. Maximum

temperatures for the day were mostly in the 70's and 80's, ranging from 75 at Drummond and Lewistown to 93 at Thompson Falls (Bushey 1989).

August 27 (Julian Date 240)

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	75F	37%	3	0.00	120%	92%	6%	10%	15%	16%	35	33
W. Glacier	78F	36%	5	0.00	115%	89%	6%	9%	15%	16%	37	38
S. Bear LO	59F	49%	2	0.03	82%	56%	8%	10%	12%	12%	50	40
S. Bear RS	76F	32%	5	0.00	110%	74%	5%	6%	14%	15%	41	43
H.Horse RS	75F	33%	2	0.00	97%	47%	6%	9%	13%	13%	46	41

Regional Weather: Regional skies for the most part cleared during the night, with sunny skies in the morning. Passage of the dry cold front during the night caused cooler nighttime temperatures and higher relative humidities to occur. Morning low temperatures ranged from 34 degrees at West Yellowstone to 51 at Billings. Many other locations reported temperatures in the 30's and 40's. Most locations had northerly winds that were light. Skies remained sunny in the afternoon as a large dome of high pressure built over the Pacific Northwest. This continued the northerly flow, warming in the western portion of the Region while the eastern half was still feeling the effects of the cool air behind the recent passage of the Canadian cold front. Afternoon temperatures were mostly in the 70's in eastern Montana, and in the 80's west of the divide. High afternoon temperatures were mostly in the 70's and 80's, ranging frorom 70 at Broadus and Lewistown to 95 at Thompson Falls. Areas of dense smoke suppressed afternoon high temperatures over southern portions of the Region and in Yellowstone National Park. Locally windy conditions occurred west of the divide with gusts to 20 MPH, but for the most part winds were less than 15 MPH across the Region.

Of the 44 stations the weather service used to monitor precipitation in Montana, 32 received no moisture during the last week. Another seven stations received 0.05" or less. No measureable precipitation was reported the last week in the southeastern, southcentral and southwestern portions of the Region. Central Montana received the greatest amounts of moisture during the one week time period and had received 49% of its normal precipitation for the growing season (April 1 to the present). Great Falls had received 64%, Stanford 90%, Harlowton 64%, Roundup 51%, and Lewistown 64% of their growing season moisture. In the northcentral portion of the Region Conrad led with 56% of its growing season moisture, while Fort Benton was 51%, Harlem 50%, Cut Bank 63%, Chester 48%, Havre 40%, and Malta with 83%. In the northeast plains Glasgow had received 62%, Medicine Lake 48%, Glendive 22%, Jordan 38%, Poplar 27%, and Sidney 27%. Polson with 113% and Libby at 104% lead northwestern Montana while Thompson Falls had received 93%, Hamilton 111%, Kalispell 88%, and Missoula with 104%. Southwestern Montana was led by Wisdom with 97%, followed by Bozeman with 90%, Belgrade 89%, Dillon 86%, Helena 74%, Lima 71%, West Yellowstone 70%, and Butte with 66%. Red Lodge led the southcentral area with 86%, Livingston 79%, Harlin 70%, Big Timber 70%, Wyola 66%, and Billings 52%. Southeastern Montana had received the least growing season moisture with Ingomar recording 53%, Broadus 39%, Ekalaka 33%, and Miles City at 19% the driest spot (Bushey 1989).

Long Range Weather Forecast: Three to five day outlook was for a warming, dry trend with scattered showers and a few thunderstorms. Six to ten day outlook was for above normal temperatures and little or no precipitation. Normal high temperatures for this time period are in the 70's (Bushey 1989).

Miscellaneous: Most of northern Idaho entered into moderate drought from their formerly moist condition as based on the Palmer Drought Severity Index. The rest of the Region and the Yellowstone area remained in areas of extreme soil dryness (Bushey 1989).

August 28 (Julian Date 241)

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	82F	28%	2	0.10	120%	92%	7%	18%	15%	16%	32	30
W. Glacier	82F	28%	2	0.00	115%	88%	5%	9%	15%	15%	38	34
S. Bear LO	70F	15%	4	0.00	78%	52%	3%	6%	10%	11%	59	55
S. Bear RS	82F	18%	8	0.00	108%	73%	3%	6%	14%	15%	43	53
H.Horse RS	80F	24%	2	0.00	96%	46%	5%	8%	13%	13%	47	43

Regional Weather: A strong ridge of high pressure aloft continued to be the dominate weather feature. The ridge axis was centered along the Washington and Idaho border. The surface pattern over the Region was very flat and the flow aloft quite weak. Most valleys were experiencing moderate temperature inversions during the morning and smoke was pooling beneath the inversion in many valleys of western Montana and northern Idaho. The temperature inversions were several hundred feet in depth and usually broke between 1100 - 1200 hrs with the development of light breezes. More exposed sites were breaking earlier (0930 - 1000 hrs). The subsidence inversion dropped considerably closer to the surface during the morning. Over the western mountains the layer of dry air was at approximately 9,000 ft, then dropped to 6,500 ft over the northern plains. Visibility was markedly reduced; West Yellowstone, Montana and Burley, Idaho reported visibility of only 3 miles, Idaho Falls and Mountain Homes in Idaho reported 5 miles, Pocatello (Idaho) 6 miles, and Boise (Idaho) 7 miles. During the night temperatures fell into the 40's and 50's, and at 0600 hrs ranged from 30 at West Yellowstone to 56 at Miles City. Sunny and dry with light winds across Montana during the afternoon. Thompson Falls had the days high temperature reading of 100 degrees, Plentywood was the coolest at 73 (Bushey 1989).

August 29 (Julian Date 242)

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	60F	79%	2	0.00	121%	93%	17%	23%	15%	16%	25	23
W. Glacier	65F	63%	10	0.00	116%	89%	11%	10%	15%	16%	34	43
S. Bear LO	71F	22%	9	0.00	76%	50%	4%	5%	8%	11%	62	71
S. Bear RS	90F	14%	7	0.00	108%	72%	3%	5%	14%	15%	45	53
H.Horse RS	85F	51%	18	0.00	96%	46%	4%	9%	13%	13%	47	42

Regional Weather: Temperature during the night dropped into the 30's and 40's, ranging from 30 degrees at West Yellowstone to 58 recorded in Boise. At 0600 hrs the subsidence inversion over the mountains varied between 8,500 and 13,000 feet in elevation between Spokane and Great Falls. Sunny skies and smoke in the valleys were the features of the day. Brisk west winds began blowing at Missoula at 1700 hrs and cleared the smoke out of the valleys. This wind was associated with a weak dry Pacific front approaching the area. This breeze possibly prevented Missoula from tying the temperature record for the date which was 94 degrees (1936, 1948). High temperatures during the afternoon were mostly in the 90's, ranging from 100 degrees at Thompson Falls to 82 at West Yellowstone. A Red Flag was issued for the Yellowstone Park area for tonight and tommorrow for winds associated with the approaching dry cold front.

Of the last 45 days in Missoula only 3 days had measurable rain. Helena reported the 33rd day with 90 or higher temperatures, breaking a record for that many days in any one year. This broke a record achieved in 1967. Their records have been maintained since 1880 (Bushey 1989).

Long Range Forecast: The three to five day outlook indicated a warming and drying trend. The six to ten day outlook called for temperatures above normal and precipitation below normal. Normal high temperatures for this time of the year are in the 70 to 80 degree range (Bushey 1989).

August 30 (Julian Date 243)

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	78F	14%	8	0.00	118%	90%	5%	17%	13%	16%	35	43
W. Glacier	80F	18%	8	0.00	113%	86%	4%	7%	13%	15%	42	50
S. Bear LO	63F	16%	6	0.00	74%	48%	3%	5%	8%	11%	64	64
S. Bear RS	79F	13%	6	0.00	104%	68%	3%	4%	12%	14%	49	54
H.Horse RS	76F	51%	17	0.00	92%	42%	3%	6%	10%	13%	54	48

Regional Weather: A weak upper trough of low pressure over the Northern Rocky Mountains produced gusty winds and slightly cooler temperatures. Temperature during the night cooled into the 50's and 60's over most of Montana, and ranged at 0500 hrs from 70 at Great Falls to 46 degrees at Butte. However temperatures were still above normal for this time of the year. Winds in the Yellowstone area reached 40 MPH as another dry cold front passed through. At

1730 hrs the entire Northern Rocky Mountain and Great Plains areas had clear skies as indicated by radar. However, at this time three large convection columns were evident over Yellowstone National Park and were interpreted to be at least 20,000' to over 25,000' in elevation. Location of the columns indicated the North Fork Fire, Clover / Mist Fire and the Mink Fire were the sources. A report from the North Fork Fire indicated the cumulus capped convection column was producing light "sprinkles" of rain (Bushey 1989).

Long Range Weather Forecast: Three to five day outlook was for fair weather that would be warmer and drier than normal. The six to ten day outlook indicated continued above normal temperatures and below normal precipitation (Bushey 1989).

August 31 (Julian Date 244)

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	75F	25%	3	0.00	116%	88%	5%	9%	14%	16%	40	56
W. Glacier	77F	29%	12	0.00	113%	86%	5%	8%	14%	15%	40	56
S. Bear LO	59F	33%	5	0.00	74%	47%	5%	5%	8%	11%	62	57
S. Bear RS	78F	17%	10	0.00	104%	68%	3%	4%	12%	14%	48	63
H.Horse RS	74F	21%	8	0.00	92%	42%	4%	7%	11%	13%	52	61

Regional Weather: High pressure building over the Region contributed to clear and dry morning skies, with temperatures cooler than previous mornings. In eastern Montana 10 MPH winds helped keep morning temperatures slightly warmer. Morning temperatures ranged from the upper 30's in Butte to the lower 60's at Miles City. The layer of very dry air (subsidence inversion) was between 8,000 - 12,000 ft with another layer of dry air over that between 12,000 - 15,000 ft. During the afternoon, sunny skies with light winds predominated across Montana. Early afternoon temperatures warmed into the mid-70's to low 80's. At 1700 hrs extremes ranged from 77 degrees at Butte to 90 degrees at Thompson Falls and 86 at Billings. In Idaho afternoon temperatures were mostly in the 80's with Mountain Home reporting 91 (Bushey 1989).

Long Range Weather Forecast: The three to five day outlook was for hot and dry. The six to ten day period was predicted to have temperatures much above normal with no precipitation. Normal high temperatures for this period are in the 70's (Bushey 1989).

September 1 (Julian Date 245)

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	78F	25%	2	0.00	115%	86%	5%	10%	13%	15%	39	35
W. Glacier	80F	23%	9	0.00	112%	86%	4%	8%	14%	15%	40	50
S. Bear LO	70F	10%	3	0.00	72%	45%	2%	4%	7%	11%	68	60
S. Bear RS	84F	13%	7	0.00	105%	69%	3%	4%	13%	14%	47	56
H.Horse RS	78F	19%	25	0.00	93%	43%	4%	7%	12%	13%	51	105

Regional Weather: Morning low temperatures ranged from 33 degrees at West Yellowstone to 54 at Billings. A ridge of high pressure continued to build in the Intermountain West with its axis along the west coast and brought warm, dry, stable air with light winds to the Northern Region. A thermal low pressure area was developing over California and Oregon. Surface high pressure was also building over eastern Montana. These factors contributed to establish an easterly airflow over western Montana (Goens 1990). Strong subsidence inversion conditions were developing across the Region and were expected to worsen as the high pressure ridge drifted east of the area. The layer of dry air that was drying fuel and causing increased nighttime fire activity dropped during the night to between 4,000 - 6,000 ft. Smoke from forest fires reduced visibility in the West Yellowstone area during the morning to less than 1/2 mile, most inversions broke in the late morning and skies cleared over these areas in the afternoon. Some Yellowstone areas remained smoked in all day. Several other locations also reported very smokey skies. Afternoon temperatures were mostly in the 80's across Montana. The highest temperatures reported in Montana were 98 degrees at Thompson Falls. High temperatures in the Yellowstone area ranged from the mid-70's to mid-80's with low afternoon humidities ranging from 9 to 15%. Washington had some unseasonably hot weather with the Quillayute area reporting temperatures in the low 90's. Clear skies prevailed over Idaho with temperatures mostly in the 80's and 90's (Bushey 1989).

Long Range Weather Forecast: The three to five day outlook was for dry and unseasonably warm weather with light winds and low humidity. The six to ten day outlook called for temperatures much above normal and little or no precipitation. Normal high temperatures for this period are in the 70's.

The long range 30 day outlook for the month of September projected temperatures near or slightly above normal and precipitation to be below normal over the Region. The 90 day outlook for September through November indicated below normal temperatures across the Region except for normal temperatures in southwestern Montana. Precipitation during the 90 day period was expected to have a better probability of being greater than normal in northern Idaho and southwestern Montana than elsewhere in the Region where moisture was expected to be slightly greater than normal (Bushey 1989)

September 2 (Julian Date 246)

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	86F	22%	3	0.00	115%	86%	5%	11%	14%	15%	38	35
W. Glacier	83F	26%	3	0.00	112%	85%	5%	8%	14%	15%	40	38
S. Bear LO	75F	15%	2	0.00	70%	42%	3%	4%	6%	10%	69	57
S. Bear RS	85F	16%	5	0.00	104%	68%	3%	4%	13%	14%	47	50
H.Horse RS	80F	21%	2	0.00	92%	42%	4%	7%	12%	13%	50	45

Regional Weather: A very strong ridge of high pressure aloft continued to build over the Pacific Northwest and the Northern Rocky Mountains. The ridge extended far to the north over western Canada. The general east wind pattern established the previous day persisted. The high pressure ridge was also helping to cause the subsidence inversion to drop in elevation over the entire Region. At 0600 hrs the inversion was at 3,500 ft in Spokane and at 4,000 ft in Great Falls. This inversion contributed to extensive thermal belt conditions, and poor fuel moisture recovery during the night. Strong, downslope east winds on the west side of the Continental Divide were also created as the subsidence inversion dropped in the evenings, causing hot, dry winds lasting from about 1700 hrs to as long as 2000 hrs in some areas. These conditions caused extreme burning conditions to last the entire night. Skies were generally clear over the Region during the night, altho a few areas had some smoke. Overnight low temperatures up to 0600 hrs ranged from 35 degrees at West Yellowstone, and 39 degrees at both Butte and Bozeman up to 56 at Billings. Hot, dry conditions were the rule across the Region during the day with several high temperature records set. Missoula equaled its record of 95 previously established in 1950, Kalispell set a new record at 93. Medford and Portland, Oregon as well as Olympia and Seattle in Washington established new record highs for the month of September. 110 degrees at Medford was the highest from that group of stations. Thompson Falls with 103 was the warmest location in Montana (Bushey 1989).

September 3 (Julian Date 247)

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	84F	27%	2	0.00	114%	86%	6%	16%	14%	15%	35	32
W. Glacier	91F	23%	2	0.00	112%	85%	5%	9%	15%	15%	39	36
S. Bear LO	77F	22%	2	0.00	70%	39%	3%	4%	7%	10%	70	56
S. Bear RS	90F	18%	3	0.00	103%	67%	3%	4%	13%	14%	47	45
H.Horse RS	88F	18%	3	0.00	91%	40%	4%	7%	12%	13%	51	48

Regional Weather: The high pressure ridge had gotten stronger and was nearly stationary, centered over the Idaho panhandle. Also at the surface; high pressure in southern Canada and east of the divide, and low pressure over Washington and Oregon continued to create an easterly pressure gradient with local northeast to southeast winds in western Montana. Livingston and Missoula

had 15 to 25 MPH east winds, while the rest of the state had mostly 5 to 15 MPH winds. These winds brought in a heavy smoke layer into the Missoula area valleys from the Canyon Creek Fire in the Scapegoat Wilderness northeast of the city. During the night skies were generally clear around Montana, except for layers of smoke in areas of western Montana. Overnight low temperatures as of 0600 hrs ranged from 39 degrees at smokey West Yellowstone to 56 at Billings. Hottest temperatures during the day, as the day before, were in the valleys of western Montana and northern Idaho where they reached into the 90's. Missoula set a new high temperature mark for the date with 98 degrees, previous high was recorded in 1967 (another severe fire season) and equaled the day before. Kalispell established another record high temperature of 97 for the date. Montana's high temperature for the day was at Thompson Falls with 99 degrees. The rest of the Region was influenced by the surface high pressure over Canada and had cooler temperatures in the 80's. Out of Region numerous records high temperatures were also being reached. In northern California the mercury rose to a blistering 116 at Redding and 117 at Red Bluff. Washington state continued to experience unseasonably hot temperatures again on this date with Moses Lake reporting 109 degrees, and 106 at Ephrata. Medford, Oregon reached 107 degrees. The coast was considerably cooler, barely getting out of the 50's. Dense smoke in portions of Idaho kept temperatures cooler in those areas, the rest of the state was in the 90's with Moscow hitting 106 (Bushey 1989).

Long Range Weather Forecast: The three to five day outlook was for continued warm and sunny days that would be a little cooler than previous days. The six to ten day outlook indicated near normal temperatures west of the Copntinental Divide and above normal temperatures to the east. Normal high temperatures for this time period are in the 70's. No precipitation or below normal precipitation was expected across the Region (Bushey 1989).

Miscellaneous: The Palmer Drought Severity Index illustrated most of northern Idaho under moderate drought conditions. An area extending through northcentral Idaho and into the western edge of Montana had become severly impacted by the drought. A small area of moist soil conditions still remained in northern Idaho, but was being continually reduced in extent with each new set of published indices. The rest of the Region was under extreme drought conditions (Bushey 1989).

September 4 (Julian Date 248)

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	84F	27%	2	0.00	114%	86%	6%	16%	14%	15%	35	32
W. Glacier	84F	24%	2	0.00	111%	85%	6%	9%	15%	15%	38	35
S. Bear LO	77F	19%	3	0.00	70%	37%	3%	4%	6%	10%	71	60
S. Bear RS	89F	18%	5	0.00	102%	66%	3%	4%	13%	14%	47	50
H.Horse RS	82F	23%	2	0.00	91%	40%	4%	5%	13%	13%	51	46

1530 hrs. Missolua Fire Weather Office Afternoon Forecast - ...Red Flag watch in affect for Monday afternoon and Tuesday all zones as winds are expected to

begin a direction shift Monday afternoon and a dry cold front with strong wind passes through Tuesday.
Discussion: High pressure over the area is about to give way to an approaching cold front off shore. This front will begin to change our weather pattern Monday afternoon as winds start to switch around to the south. The timing of the front is difficult at this time, but indications are it will pass through the Idaho panhandle and northwestern Montana tuesday morning, and move east of the Divide late in the day.
Zone 104: Tonight...
Weather: Fair skies, some valley areas having smoke settle in for the night.
LAL: 1 CWR: zero
Minimum Temperatures: Relatively mild...45-55 with some warmer ridges and colder temperatures in the bottom areas.
Maximum Humidities: Still generally poor recovery...40-55% most areas.
Surface Winds: Easterly across ridges and up drainages, mainly 3-8 MPH. Otherwise generally downslope 0-5 MPH.
Monday....
Weather: Smokey...Otherwise fair.
LAL: 1 CWR: zero
Maximum Temperatures: Warm...mostly 80-95.
Minimum Humidities: Dry...13-20%.
Surface Winds: Easterly morning into the afternoon, 5-10 MPH, but slowly becoming southerly late in the afternoon, 5-10 MPH.
Free Air Winds: Southerly 10 MPH.
Outlook for Tuesday...
Dry cold front passage with strong winds developing...10-20 MPH with stronger gusts. Much cooler...max temps down 10-15 degrees. Humidity up 5 to 10%.
3 to 5 Day Outlook...Wednesday through Friday...
Windy, especially Wednesday and Thursday...slight chance of mountain showers thursday and Friday...cooler and humidity up. Winds westerly.

Regional Weather: The strong high pressure ridge remained fixed in position over the Northern Region. The surface high previously over eastern Montana moved east over the Dakotas lessening the pressure gradient, winds were generally light and slope induced (Goens 1990). Strong subsidence inversionconditions existed across the entire Region, at the surface in Boise and Spokane and at 8,500 ft in Great Falls. This inversion caused poor nighttime fuel moisture recovery in most areas. Overnight skies were clear over most of Montana except for areas of smoke. Low temperatures as of 0600 hrs ranged from 38 degrees at smokey West Yellowstone to 58 at Glasgow. Visibility was restricted to 1/8 of a mile during the morning at West Yellowstone. Missoula was under approximately 95% cover of smoke at an elevation starting at 5,000 ft. Afternoon temperatures were slightly cooler than the previous days, but not by much. Temperatures were still 10 to 20 degrees above normal for this time of the year. Missoula reached 94 degrees and was only 1 degree short of tying the previous record established in 1967. Thompson Falls reached 102, Superior attained 100 degrees. Lewiston, Idaho reached the century mark for the afternoon high temperature (Bushey 1989).

September 5 (Julian Date 249)

Pat Hanley, a logger on one of the timber sale units within the Red Bench Timber Sale area described the weather pattern on the night of September 5 and the day of the 6th as "scarey." Conditions were described as the hottest and most windy period of the year (Hurd 1988).

Calculated 1-Hour Timelag Fuel Moisture in the vicinity of the fire origin under 100% canopy was approximately 7.3 - 7.4%, Probability of Ignition of 40% during the afternoon and evening on this date. Fuel level temperatures ranged from approximately 69F-84F. (Behave Moisture Module)

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	82F	33%	2	0.00	114%	85%	7%	15%	15%	15%	35	32
W. Glacier	86F	28%	2	0.00	112%	85%	5%	10%	15%	15%	38	35
S. Bear LO	76F	21%	5	0.00	70%	36%	4%	4%	6%	10%	71	65
S. Bear RS	89F	22%	3	0.00	103%	66%	4%	5%	14%	14%	46	44
H.Horse RS	82F	25%	0	0.00	93%	41%	5%	8%	13%	13%	48	42

1530 hrs. Missoula Fire Weather Office Afternoon Forecast - ...Red Flag warning for tonight for a wind shift to the south and southwest and a Red Flag Warning for Tuesday for increasing west winds behind the cold front.
Discussion: The strong high pressure that has been over us is begining to break down as an approaching cold front speeds east toward us. This front is expected into the northern Idaho panhandle Tuesday morning and to be into eastern Montana late in the afternoon. Another system will come right on its heels for strong west winds Wednesday. After a few days of cooler, more humid weather, high pressure is expected to rebuild over the Northwest during the weekend.
Zone 104: Tonight...
Weather: Smokey, quite thick in some areas.
LAL: 1 CWR: zero
Minimum Temperatures: Generally 45-55.. Cooler under thick smoke and bottom areas.
Maximum Humidities: Recovery generally fair cooler areas...near 60%. Recovery poor slopes and ridges...35-40%.
Surface Winds: Becoming south to southwest ridge level, 3-8 MPH.
Tuesday...
Weather: Some high clouds...Cold front moving across zones by midday.
LAL: 1 CWR: zero
Maximum Temperatures: Much cooler...75-82.
Minimum Humidities: Higher...20-25%.
Surface Winds: Becoming west to southwest 10-20 MPH and gusty.
Free Air Winds: 25-30 MPH.
Outlook for Wednesday...
Partly cloudy and cooler and windy. slight chance Zone 104 of mountain showers. Winds west 10-15 MPH and gusting to 25 MPH...Temps down about 8 more degrees...Humidity up 5- 10%.
3 to 5 Day Outlook...Thursday through Saturday.
Still breezy thursday and into Friday. Warmer Saturday... Max Temps mid 60s to mid 70s Thursday, warming to the mid 70s to low 80s Saturday.

Winds west to northwest.

Regional Weather: Skies were generally clear across Montana with layers of smoke aloft over portions of southern and western Montana. Generally light, variable winds during the night (less than 10 MPH) kept the smoke from being cleared from the valleys. West Yellowstone reported visibility was reduced to 1/16 of a mile, in Livingston visibility was reported as low as 1/4 mile at times. Temperatures at 0600 hrs ranged from 34 degrees at West Yellowstone to 58 at Billings. Most readings were in the low to mid-50's. During the morning the NWS issued Red Flag Watches for western Montana and northern Idaho for the up coming night and the 6th. These watches were for gusty winds, low humiditues, and warm temperatures associated with a frontal passage. Red Flag Watch was also issued for eastern Montana for the same period for gusty westerly winds and low humidities. The Canyon Creek Fire was obviously in a warm, dry sector in front of the approaching cold front. Winds during the night would remain light to calm. Afternoon temperatures ranged from the mid-80's to the lower 90's. Missoula reported a high temperature of 94 degrees which set a new high temperature mark for the date. The previous record temperature had been established in 1960 at 93 degrees. Glasgow reported winds of 10 to 20 MPH, while the remaining portions of the state generally had light winds. Idaho reported clear but smokey skies with similar afternoon temperatures as Montana. Washington had low clouds and drizzle in the west with temperatures mostly in the 60's from the cold front moving in off the Pacific. The front moved slower than expected and did not arrive in the Region during the afternoon or night.

September 6 (Julian Date 250)

0653 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 8 MPH, north-northwest
Maximum Wind Gust and Direction: 16 MPH, north-northwest
Temperature: 67F
Relative Humidity: 32%
1-Hour and 10-Hour Fuel Moisture: 8% and 10%

NOTE: Cyclone Peak RAWS is on a northeast aspect at 5,312 feet msl elevation. Wind speeds and wind directions at this station are prone to being strongly influenced by deflected and eddied wind currents, especially from strong winds from the west and northwest which occur with passing weather fronts. As a result wind readings at this station will not accurately reflect conditions experienced on the Red Bench Fire under west to northwest winds. The RAWS unit located at Spotted Bear Lookout in the Bob Marshall Wilderness to the southeast can be considered a good example of free air conditions.

0753 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 3 MPH, south-southwest
Maximum Wind Gust and Direction: 14 MPH, north
Temperature: 67F
Relative Humidity: 34%
1-Hour and 10-Hour Fuel Moisture: 8% and 10%

0800 hrs. Missoula Fire Weather Office Morning Forecast - ...Red Flag today...Wind and Frontal Passage.

Winds west to northwest.

Regional Weather: Skies were generally clear across Montana with layers of smoke aloft over portions of southern and western Montana. Generally light, variable winds during the night (less than 10 MPH) kept the smoke from being cleared from the valleys. West Yellowstone reported visibility was reduced to 1/16 of a mile, in Livingston visibility was reported as low as 1/4 mile at times. Temperatures at 0600 hrs ranged from 34 degrees at West Yellowstone to 58 at Billings. Most readings were in the low to mid-50's. During the morning the NWS issued Red Flag Watches for western Montana and northern Idaho for the up coming night and the 6th. These watches were for gusty winds, low humiditues, and warm temperatures associated with a frontal passage. Red Flag Watch was also issued for eastern Montana for the same period for gusty westerly winds and low humidities. The Canyon Creek Fire was obviously in a warm, dry sector in front of the approaching cold front. Winds during the night would remain light to calm. Afternoon temperatures ranged from the mid-80's to the lower 90's. Missoula reported a high temperature of 94 degrees which set a new high temperature mark for the date. The previous record temperature had been established in 1960 at 93 degrees. Glasgow reported winds of 10 to 20 MPH, while the remaining portions of the state generally had light winds. Idaho reported clear but smokey skies with similar afternoon temperatures as Montana. Washington had low clouds and drizzle in the west with temperatures mostly in the 60's from the cold front moving in off the Pacific. The front moved slower than expected and did not arrive in the Region during the afternoon or night.

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0753 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 3 MPH, south-southwest
Maximum Wind Gust and Direction: 14 MPH, north
Temperature: 67F
Relative Humidity: 34%
1-Hour and 10-Hour Fuel Moisture: 8% and 10%

0800 hrs. Missoula Fire Weather Office Morning Forecast - ...Red Flag today...Wind and Frontal Passage.

Discussion: Pacific front located on a Spokane-Pendleton, Oregon line early this morning. Front expected along Kalsipell-Lewiston, Idaho line by late morning and continuing to move southeast at about 25 MPH. It should enter our southern zones by mid afternoon. Cooler westerly flow Wednesday and likely Thursday with broad upper level trough of low pressure over area.

Zone 104: Today...

Weather: Areas dense smoke dispersing late morning.. early afternoon. Becoming partly cloudy.
LAL: 1 CWR: zero
Maximum Temperatures: 75 to 85
Minimum Humidities: 15 to 30%...rising some afternoon.
Surface Winds: SE to W 10 to 20 with 30 higher elevations afternoon.
Free Air Winds: S to SW 20 becoming west 30 afternoon.

Tonight...

Weather: Partly cloudy.
LAL: 1 CWR: zero
Mimumum Temperatures: 40 to 50
Maximum Humidities: 70 to 80% bottoms...50 to 60 ridges/slopes
Surface Winds: Wind becoming variable 2 to 8 except SW to NW 10 to 20 more exposed areas.
Free Winds: West 25.

Tomorrow...

Weather: Variable cloudiness. Chance few light showers.
LAL: 1 CWR: 10%
Maximum Temperatures: 65 to 75
Minimum Humidities: 25 to 35%
Surface Winds: Variable 3 to 8 with westerly 15 to 20 more exposed areas.
Free Winds: West 25.

3 to 5 Day Outlook Thursday through Saturday...

Cooler and windy at times. Slight chance of showers in northern zones. High 60s and 70s mountians and 70s to low 80s low elevations. Lows 40s with 25 to 35 high elevations.

6 to 10 Day Outlook...Sunday September 11 through Thursday September 15.
Temperature: above normal Precipitation: below normal

Smoke Dispersion Forecast....

Dispersion becoming good northern zones by late morning...and southern zones this afternoon. Fair to good dispersion tonight and Wednesday...winds with frontal system today dispersing most smoke areas...fires in steep, sheltered areas likely to have poor dispersion. Late tonight and Wednesday morning with downslope winds...see wind forecast above for transport etc.

0830 hrs. - Fire Behavior Warning - RICO Fire Behavior Service Center

The dry cold-front that had been predicted is starting to track into the Region. On a line this morning Spokane-Pendleton, should be on a line between Kalispell-Lewiston by late morning. Expect it to move at 25 MPH and be in our southern zones by mid afternoon. Currently there is no indication of a reverse wind profile, just increasing winds with increasing elevation. 0600 hr soundings from Spokane this morning had 25 MPH southwest winds at 2000', 30 MPH southwest winds at 5000', 35 MPH southwest winds at 8000', and 40 MPH southwest winds at 15,000'. Lookout stations on the west side of the Kootenai National Forest reported 30-35 MPH southwest winds, and all was calm below. Calm on the

1353 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 13 MPH, north
Maximum Wind Gust and Direction: 29 MPH, north
Temperature: 72F
Relative Humidity: 21%
1-Hour and 10-Hour Fuel Moisture: 4% and 8%

1400 hrs **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	76F	23%	6	0.00	114%	86%	6%	15%	15%	15%	36	40
W. Glacier	--F	--%	-	0.00	---%	--%	-%	-%	--%	--%	--	--
S. Bear LO	67F	24%	22	0.00	70%	34%	4%	4%	6%	9%	71	119
S. Bear RS	84F	18%	15	0.00	103%	66%	3%	4%	13%	14%	47	75
H.Horse RS	82F	13%	20	0.00	93%	41%	3%	7%	13%	13%	50	93

1-Hour Fuel Moisture at the fire origin site was calculated to be 7.4% with a Probability of Ignition of 40% at the fire origin site from 1200-1700 hrs. Fuel level temperatures were estimated at 70F between 1200-1500 hrs, then started to decline to 68F by 1700 hrs.

1400 hrs. Fire was first observed by a member of Pat Hanley's crew in the southwest 1/4 of southwest 1/4, section 16, T35N, R22W. Pat Hanley reported the fire to Glacier View Ranger District, Flathead National Forest.

Estimated smoldering combustion average rate-of-spread from a single source ignition in duff is approximately 1.2 inches (3 cm) per hour (Bill Fransen, Intermountain Fire Sciences Laboratory, Missoula, MT, personel communication). Other studies have shown rate-of-spreads of 0.5 to 10 cm in Tasmania (Sheshukov 1974); Australia rule-of-thumb rate-of-spread used by fire control personnel are about 1.6 inches (4.1 cm) per hour while 1.2 to 4.8 inches (3 to 12 cm) per hour have been calculated from peat fires (Weir 1983). Using this average ROS for the 473 hours between the lightning strike and time of discovery the smoldering combustion would have had the opportunity to travel a circular radius of 47.3 feet, with an area of 7,029 square feet or 16.1% of an acre. Microclimate conditions under the closed tree canopy for the time period were relatively constant with no precipitation and only 20 hours (4.2%) when open atmospheric conditions had a relative humidity of 100% [67 hrs (14.2%) of 80% or greater]. Increased wind turbulence from the approaching dry cold front would have increased flame length and rate-of-spread in areas of dead and down fuel around the circumference of the burned out ground and surface fuel allowing ladder fuel to carry the fire into the tree canopy.

Preburn the origin site was a dense overstory of subalpine fir and lodgepole pine. The understory contained small subalpine fir and heavy menziesia (Hurd 1988). Fuel conditions on this fire were some of the most severe in the North Fork of the Flathead River country. The area which would be involved by the fire was dominated by dense stands of decandent lodgepole pine and heavy spruce pockets. Snag densities of 500 to 1500 stems per acre were common. Total standing and down dead fuel loadings range from 100 to 300 tons per acre (Red Bench Fire Executive Summary). Average duff depth was approximately 3" in the vicintity of the fire.

1353 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 13 MPH, north
Maximum Wind Gust and Direction: 29 MPH, north
Temperature: 72F
Relative Humidity: 21%
1-Hour and 10-Hour Fuel Moisture: 4% and 8%

1400 hrs **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	76F	23%	6	0.00	114%	86%	6%	15%	15%	15%	36	40
W. Glacier	--F	--%	-	0.00	---%	--%	-%	-%	--%	--%	--	--
S. Bear LO	67F	24%	22	0.00	70%	34%	4%	4%	6%	9%	71	119
S. Bear RS	84F	18%	15	0.00	103%	66%	3%	4%	13%	14%	47	75
H.Horse RS	82F	13%	20	0.00	93%	41%	3%	7%	13%	13%	50	93

1-Hour Fuel Moisture at the fire origin site was calculated to be 7.4% with a Probability of Ignition of 40% at the fire origin site from 1200-1700 hrs. Fuel level temperatures were estimated at 70F between 1200-1500 hrs, then started to decline to 68F by 1700 hrs.

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Preburn the origin site was a dense overstory of subalpine fir and lodgepole pine. The understory contained small subalpine fir and heavy menziesia (Hurd 1988). Fuel conditions on this fire were some of the most severe in the North Fork of the Flathead River country. The area which would be involved by the fire was dominated by dense stands of decandent lodgepole pine and heavy spruce pockets. Snag densities of 500 to 1500 stems per acre were common. Total standing and down dead fuel loadings range from 100 to 300 tons per acre (Red Bench Fire Executive Summary). Average duff depth was approximately 3" in the vicintity of the fire.

Dead and down data from Unit 3 was considered typical for all three logged units which became involved in the fire: 0-1/4" diameter fuel, 1.5 tons per acre; 1/4-1" diameter fuel, 2.5 ons per acre; 1-3" diameter fuel, 10 tons per acre; total dead and down fuel loading 39 tons per acre. Habitat Type: Abla/Clun (620), Aspect North-Northwest, Slope 55%, NFDR Fuel Model 12 (Flathead National Forest Burning Plan, Red Bench Unit 3). Logging Units 1-3 were logged during the 1987 operating season. The Forest Service had burned landing piles in both Units 1 & 2 in late fall 1987. Unit 4 finished being logged last week of July 1988. Unit 6 completed August 24 (Reply to Glacier View District Ranger Tom Hope on Red Bench 2450 Sales contracts and Permits from Clarence R. "Bud" Anderberg Sales Administrator). Unit's 4 and 6 would not be involved in the fire.

1425 hrs. Howard McMillan at the District Office notified Flathead National Forest Dispatch in Kalispell of the reported fire incident and requested aerial reconnaissance.

Flathead National Forest Dispatch called the Cyclone Peak Lookout to confirm smoke over toward Red Meadow Creek, but the visibility reported by the Cyclone Peak Lookout earlier at 1340 hrs at 1 mile had not improved and the fire was not visible. Cyclone Peak Lookout is approximately six air miles southeast of the fire origin. Thick smoke from the Dry Fork Fire on the Kootenai National Forest had restricted visibility at the Cyclone Peak Lookout for the previous three days. Mary Peterson at the lookout replied that drift smoke was to thick. Air patrol 6HA was directed to the reported incident with Richard Hildner as observer (Bunnell 1988, Mary Peterson).

In his initial radio report, Hanley indicated that there was no fire on the east side of the ridge at this time. However, the fire was actively burning several hundred yards above the road leading to the Red Bench Timber Sale. The fire was reported at less than 1/4 acre. In the preliminary wildland arson investigation, Bob Hurd discovered the origin to be about 100 yards above the logging road on the sidehill. He was unable to locate a lightning struck tree, but did observe several burned out stump holes in the general origin area. There was no evidence of human activity found in the vicinity of the fire origin (Hurd 1988).

Hanley mustered the logging crew and attacked the fire immediately with all 16 men and 3 crawler tractors. Primary suppression effort consisted of cutting line up the west flank and along the bottom of the fire to stop downhill backing to the logging road. After cutting line up the west slope and stretching 200 feet of hose which just reached the lowest portion of the fire, Hanley scouted the ridge. Later established a partial line between fire and road approximately 30 feet upslope. There was quite a bit of smoke in the area and the fire was backing downslope toward the crew.

1431 hrs. Engines 71 and 72 and crews are dispatched from Big Creek Work Center (Bunnell 1988), approximately 18 miles southeast of the road in to Red Meadow Creek.

1440 hrs. Aerial patrol 6HA was airborne.

1445 hrs. The wind shifted and the smoke cleared just prior to Aerial patrol 6HA arriving. At this time Cyclone Peak Lookout was also able to see smoke coming up over the ridge separating Hay Creek and Red Meadow Creek. Shortly

after the smoke became visible to the lookout the wind velocity increased considerably (Mary Peterson).

1453 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 7 MPH, north-northeast
Maximum Wind Gust and Direction: 28 MPH, northeast
Temperature: 75F
Relative Humidity: 20%
1-Hour and 10-Hour Fuel Moisture: 4% and 8%

1453 hrs. Aerial patrol 6HA approached the fire and gave it's assessment of the fire and fuel conditions. It was determined that the site was suitable for retardant. The smoke column was not well developed, smoke was light and whispy and fire spread did not appear to be influenced by the strong winds which were blowing west at an estimated 30 MPH. Fire at this time was approximately 1/4 acre in size and about 40 meters above the road. No fire had become established in the forest canopy. Soon after their arrival the first trees began to torch. Once torching was initiated the fire came under the influence of the west winds and in short order spotting controlled the advance of the fire (Richard S. Hildner).

1500 hrs. Hanley walked the west flank to the ridge top. He observed fire throughout the drainage to the east and realized the fire was beyond his crew's capabilities. He then pulled his crew off of the fire for safety reasons (Bunnell 1988, Hurd 1988).

1505 hrs. Retartdant ordered from Regional Coordinators Office in Missoula, they responded that Lead 91 and Tanker 160 would be over the fire about 1545 hrs. Hildner suggested loggers should secure and move out equipment as fire was becoming very active. Hildner estimated the fire had grown to 2 acres and suggested 5 crews due to heavy down fuel and spotting. Hildner noted that fire was rolling and any crews approaching area should use extreme caution to avoid trapping on Hay Creek Road (Bunnell 1988).

1520 hrs. All Glacier View Ranger District personnel were headed for the fire at this time, additional crews were not available in the Northern Region. Orders for additional crews were estimated to be delayed for three days and would have to come from out of Region. Flathead National Forest dispatch orders personnel from the Swan Lake District to the fire (Bunnell 1988).

1525 hrs. Engines 71 and 72 approach fire area and are directed by aerial patrol 6HA (Bunnell 1988).

1526 hrs. Tom Hope, Glacier View District Ranger, placed an order for a Type I Overhead Team (Bunnell 1988).

1530 hrs. Missoula Fire Weather Office Afternoon Forecast - ...Red Flag warning for tonight and Wednesday morning for very strong westerly winds. Discussion: A dry cold front went through the Region today and will speed to the east this evening and tonight...strong winds are building behind the passage of this system...mainly along the Northern Rockies and along the Canadian border.
Zone 104: Tonight...
Weather: A few high clouds. Smokey.

LAL: 1 CWR: zero
Minimum Temperatures: Cooler...38-45.
Maximum Humidities: Recovery a little better...50-60% most areas.
Surface Winds: West to Northwest 15-20 MPH with gusts to 35 MPH.
Wednesday...
Weather: Fair...a few high clouds.
LAL: 1 CWR: zero
Maximum Temperatures: Cooler...65-75.
Minimum Humidities: Higher...25-30%.
Surface Winds: Northwest to West 10-20 MPH gusts to 30 MPH decreasing late in the day.
Free Air Winds: Northwest 45 MPH.
Outlook for Thursday...
Mostly sunny...less wind though still Northwest to West 5-10 MPH and gusty. Temps and Humidities about the same.
3 to 5 Day Outlook...Friday through Sunday...
Cooler and more humid...some chance of precipitation in the northern zones. Temps possibly into the 60s by Sunday.

Forecast Revisions carried up by Incident Fire Behavior Analyst (FBA) Pat Velasco after talking with Missoula Forecasters;
Tonight...
Maximum Temperatures: 38 to 45
Minimum Humidities: 50 to 65% bottoms
Surface Winds: west to northwest 15 to 20 MPH gusts to 35 MPH
Tomorrow...
Weather: Becoming sunny later in the day
Minimum Humidities: 15 to 30%
Surface Winds: N to NW 10-20, gusts to 30 decreasing late in day
Thursday... Mostly sunny..less wind though still NW to W 5-10 MPH and gusty. Temps and humidities about the same.

1553 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 15 MPH, north
Maximum Wind Gust and Direction: 42 MPH, north-northeast
Temperature: 70F
Relative Humidity: 19%
1-Hour and 10-Hour Fuel Moisture: 4% and 7%

1605 hrs. Aerial patrol 6HA reports fire on both sides of the road and logging unit 2 involved (Bunnell 1988).

Almost instantaneous flashover over the first ridge with a rolling ball of fire approximately 1/4 mile wide. Fire was shaped like a basketball and appeared to bounce and pulse as it traveled over the landscape pushed by the wind. The fire ran the first mile in approximately 1 hour. The first 20 minutes to 1/2 hour the fire did not spot below the road. Once spotting had occurred in the cutting units below the main fire, spread was characterized by a slow backing fire moving down slope. Above the fire, spread was more rapid as the flaming flanks took advantage of heavy standing dead fuel and upslope conditions. The rear didn't seem to spread more than 20 meters to the west (Richard S. Hildner).

1610 hrs. Hildner estimates fire is 40 acres and spotting (Bunnell 1988).

The fire hooked through Unit 1 and into the basin in Section 15 to the immediate east. Unit 1 burned hot (Clarence R. "Bud" Anderburg).

Fire flanked into cut units with an approximately rate-of-spread of 1 chain per hour (Richard S. Hildner).

Strategy is to use retardant on west flank to keep fire from backing into the wind, the head of the fire is a complete runaway (Bunnell 1988).

1615 hrs. Decision is made to attack southwest flank with retardant as wind permits and to start advising homeowners in the bottoms of Red Meadow Creek of the impending danger.

1620 hrs. First retardant drop is on the south end of the west flank. Additional tankers enroute that have been diverted from other fires due to high winds at those locations (Bunnell 1988).

Tried dropping retardant on fire, rough air caused irregular dispersal (Clarence R. "Bud" Anderburg).

1630 hrs. McMillian (Glacier View District Safety / Fleet Officer) is directed to the Polebridge General Store to inform local residents of the current fire situation and suppression actions (Bunnell 1988).

1633 hrs. Engines 71 and 72 are moved in to pre-structural protection positions in Red Meadow Creek. These were shortly joined by Engine 007 from the Swan Lake District. Flathead National Forest dispatch calls Sheriff's Office for assistance in Red Meadow Creek potential evacuation (Bunnell 1988).

1640 hrs. Fire is estimated to be 1 3/4 miles long and 1/4 mile wide. Air tankers experiencing 2,000 feet per minute drift. "It is getting hairy and scary in the sky!" (Bunnell 1988).

Helicopter 493 reports 50 MPH headwinds trying to return to Kalispell. Air tankers were having no success at holding southwest flank, they throw their last loads and return to Kalispell with heavy, erratic winds. The potential for a Burnout Operation from Red Meadow Road is discussed, but is delayed due to strong winds and a lack of personnel. Loggers and their equipment are reported to be ok on the west end of the fire (Bunnell 1988).

1653 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 18 MPH, north-northwest
Maximum Wind Gust and Direction: 36 MPH, north-northwest
Temperature: 69F
Relative Humidity: 21%
1-Hour and 10-Hour Fuel Moisture: 4% and 7%

1730 hrs. Fire exhibits some long range spotting that exceeds Spruce Creek Road ending the possibility for a Burnout Operation (Bunnell 1988).

Spotting at least 1 1/2 miles ahead of main fire. Spot fires very active, would ignite within a few moments and immediate climb into trees. Mostly small branch material were being carried and causing the spot fires, branches up to 4" in length and 1/4" in diameter (Clarence R. "Bud" Anderburg).

1753 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 7 MPH, north
Maximum Wind Gust and Direction: 39 MPH, north-northeast
Temperature: 65F
Relative Humidity: 21%
1-Hour and 10-Hour Fuel Moisture: 5% and 7%

1759 hrs. Fire had jumped the Spruce Creek Road. Long range spotting is a problem (Bunnell 1988).

1800 hrs. Type I Team dispatched from Missoula. A Type I Overhead Team (Bob Wagenfer from Region 3) had just been released from the Lolo Creek Fire south of Missoula during the late afternoon, and were being debriefed on that fire. Wagenfer's Team was assigned to the Red Bench Fire and briefed on the current situation on the new fire. Pat Velasco, Fire Behavior Anaylst with the team received information on fuel types to be expected in the fire vicinity, available RAWS and AFFIRMS weather stations, maps, and updated weather forecasts from the RICO Fire Behavior Service Center and the Missoula Fire Weather Office. The Team was also made aware of the potential for a wildland / urban interface fire problem on private lands between the Flathead National Forest and Glacier National Park, and down wind of the fire. Estimated size at 1800 hrs was 700 acres and growing fast (Red Bench Fire Executive Summary).

Approximately 1830 hrs. The flaming front became visible to the Cyclone Peak Lookout as it moved from behind the ridge out toward the Red Meadow Bench. The fire "front" was initially wind driven flames traveling thru the top 1/3 of the tree canopy. Flames were estimated to be up to 500 feet in length (not height), based on local tree heights, angled at approximately 35-40 degrees. This front was a deep orange mixed with thick black smoke and was highly visible because the wind was driving the smoke away from the flames and the Cyclone Peak Lookout was above and behind the flaming front. As this front moved thru the tree tops the tops of dead lodgepole pine (the clusters of pine cones were visible at the tops of these flying Christmas trees) were broken off. These 8-10 foot tree top flaming pieces could be seen spiralling in to the convection column then dropping to the ground between 1/4 and 3/4's of a mile ahead of the main tree top flaming front. As these pieces crashed to the ground the surrounding vegetation burst into flame. The spot fires would quickly crown and were quickly tear-drop shaped fires moving ahead of the main crown fire front. For 15 to 20 minutes following this tree top crown fire front the remaining crowns of the forest canopy would burn with a deep red color in a mass fire situation behind the front. A distinct ground fire front followed this period moving through the ground fuel up to 15-30 minutes after the tree top crown fire front had initially arrived in the same locations (Mary Peterson).

Mary Peterson was pulled from the Cyclone Peak Lookout during this evening because of the fear the fire would burn over the ridge and advance toward the tower to the south of the fire. Mary would return to the station later on the 7th to provide observations and weather reports to the fire crews, then again be pulled as the winds shifted out of the north-northwest and down drainage of the North Fork of the Flathead River. She was assigned to the Logging Creek Fire Camp. While she was gone Bob Hurd collected the Lookout Log and a calander on which Mary kept fire notes for safe keeping (Mary Peterson)

Approximately 1830 hrs. Flathead National Forest dispatch requests a general public message be broadcast over public radio stations regarding Red Meadow evacuation procedure. The request is okayed by the Sheriff's Office and the Tom Hope, District Ranger. The County disaster coordinator is informed (Bunnell 1988).

1830 hrs - **Special Fire Behavior Warning** - Rico Fire Behavior Service Center.

Inform all fire camps immediately. A low level reverse wind profile has developed from the 1800 hrs Spokane balloon sounding. This feature can cause very rapid and extreme fire behavior on any fire. Following are the wind speeds at the various elevations.

2000'	25 MPH
3000'	35 MPH
4000'	40 MPH
4500'	35 MPH
6000'	40 MPH
7000'	45 MPH
8000'	35 MPH
9000'	30 MPH
10000'	30 MPH
12000'	35 MPH
14000'	40 MPH
16000'	50 MPH
19000'	55 MPH

Elevations are approximate. (Chuck Bushey, FBA, Fire Behavior Service Center, RICO Planning Section, this was sent by DG computer electronic mail to the Flathead National Forest Dispatch then followed by a phone call to the Dispatch Office. The warning was noted as received by Incident FBA Pat Velasco at 1000 hrs on 9/7)

1832 hrs. Heavy wind and spotting are reported on the main ridge above Spruce Creek (Bunnell 1988).

1853 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 15 MPH, north-northwest
Maximum Wind Gust and Direction: 37 MPH, north-northwest
Temperature: 64F
Relative Humidity: 27%
1-Hour and 10-Hour Fuel Moisture: 6% and 7%

Approximately 1900 hrs. Aerial patrol 6HA reports a spot in section 11 about 1/4 acre and getting bigger. Enough personnel, engines, and cats are available to attempt a direct attack on the west side of Spruce Creek Raod (Bunnell 1988).

1920 hrs. A cat line is started west of Spruce Creek Road, reinforced by two engines and three crews. Red Meadow Creek evacuation procedures begin and traffic is blocked in to the area (Bunnell 1988).

1953 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 8 MPH, north
Maximum Wind Gust and Direction: 32 MPH, north-northeast
Temperature: 62F
Relative Humidity: 34%
1-Hour and 10-Hour Fuel Moisture: 7% and 7%

2053 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 12 MPH, north
Maximum Wind Gust and Direction: 37 MPH, north-northeast
Temperature: 62F
Relative Humidity: 40%
1-Hour and 10-Hour Fuel Moisture: 8% and 8%

2030 hrs. The wind drives the fire at the cat line and exceeds the lines holding capacity (Bunnell 1988).

2030 hrs. The advance group of the Type I Team arrived at the fire and held preliminary discussions with representatives of the Flathead National Forest, Glacier National Park, and civil authorities. This meeting produced the letter of delegation for the team, EFSA for the Forest and Park, and a description of the current fire situation. At this time the fire appeared to be bearing down on approximately 20 dwellings with very few suppression resources available to check the fire's spread (Loving 1988).

Fuel Model 10, very heavy fuels. 2 mile rate-of-spread in 2 hrs. 1 mile wide, 2 miles long, backed up about 1 chain (Pat Velasco, Incident FBA; initial assessment of fuel and fire behavior).

2040 hrs. Line is abandoned at the Spruce Creek Road (Bunnell 1988).

2153 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 22 MPH, north
Maximum Wind Gust and Direction: 49 MPH, north-northwest
Temperature: 62F
Relative Humidity: 40%
1-Hour and 10-Hour Fuel Moisture: 8% and 8%

Calculated 1-Hour Fuel Moisture for conditions at 4,300 feet msl elevation in a managed forest stand ranged from 6.6% to 7.3% between 1200 - 2100 hrs. Probability of Ignition declined from 50 to 40% during this period. Fuel level temperatures dropped from an estimated 76F to 66F. The fire burned through this location at approximately 1900 hrs.

2230 hrs. A second effort to catline is eventually overrun by spotting and high winds (Bunnell 1988).

2253 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 17 MPH, north
Maximum Wind Gust and Direction: 44 MPH, north
Temperature: 60F
Relative Humidity: 39%
1-Hour and 10-Hour Fuel Moisture: 8% and 9%

2353 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 11 MPH, north-northwest
Maximum Wind Gust and Direction: 42 MPH, north
Temperature: 59F
Relative Humidity: 40%
1-Hour and 10-Hour Fuel Moisture: 9% and 10%

1-Hour Fuel Moisture were calculated under conditions similar to the fire origin location (unburned) continued to rise steadily from the 1700 hr reading of 7.4% to approximately 9.6% at midnight. Probability of Ignition declined from 40% to 30% during this time period.

Regional Weather: Red Flag Warnings issued for this day in western Montana and northern Idaho, and the Greater Yellowstone area for winds associated with the frontal passage. Red Flag watch in eastern Montana was changed to a warning.

The strong, high pressure system had weakened and moved to the south. Skies remained mostly sunny, with smoke obscuring the sun and reducing visibility in western Montana. Visibility was reduced at times to 1/8 of a mile at West Yellowstone and down to 2 miles in the Livingston area. An examination of radiosonde stations between the Region and the US and Canadian west coast showed no indication of a low level reverse wind profile. Winds from stations near the front were indicating surface winds of 25 to 35 MPH. Similar to other recent dry cold front passages. Lookout stations on the westside of the Kootenai National Forest reported morning (0800 hrs) winds of 30 to 35 MPH out of the southwest and calm conditions at lower elevations. Wind conditions were calm (1 - 5 MPH) on the Clearwater and Nez Perce National Forests. Free air winds at 0900 hrs at the Silver King Lookout south of the Canyon Creek Fire were 16 MPH from the west. Front position by 0900 hrs was from about Bonners Ferry-west of Grangeville. By 1000 hrs winds on the Clearwater and Nez Perce National Forests were between 2 to 12 MPH with gusts to 30 MPH. By 1200 hrs the front was on a line west of Kalispell-east of Grangeville. A surface low pressure trough developed about 1200 hrs on the east side of the Northern Rocky Mountains. Winds along the front were reported as 8 to 15 MPH with gusts to 30 MPH. As the front passed into the Northern Rocky Mountains it stalled and it became difficult to discern its exact location. Winds on the Clearwater National Forest peaked at 1300 hrs with 7 to 30 MPH winds gusting to 35 MPH and shifting from southwest to northwest. By 1400 hrs the winds on this Forest had started to decrease (7 - 20 MPH, gusts to 30 MPH). 1400 hrs winds on the Storm Creek Fire on the Custer National Forest were reported as 5 to 12 MPH with 22 MPH on the Ridgetops, and 8 to 10 MPH on the Dry Fork Fire in northwest Montana. Winds at the Silver King Lookout on the Helena National Forest about 1400 hrs indicated that the Canyon Creek Fire winds were increasing with 20 MPH gusts. A helibase log on the fire indicated 50 knot winds aloft. 1430 hrs winds were 20 MPH in West Yellowstone, and 8 to 10 MPH with gusts to 20 MPH on the Combination Fire (Deerlodge National Forest). At 1445 hrs light winds in Missoula became steady out of the south and southwest 12 to 20 MPH, gusts to 26 MPH then started to decline in speed. Surface winds on the Canyon Creek Fire gusted to 50 MPH, with 42 MPH gusts measured by the Monture RAWS. Winds at this RAWS unit had been averaging near 20 MPH since 1400 hrs. A strong low level reverse wind profile was indicated by the 1600 hr radiosonde reading from Spokane with winds out of the west-southwest. Visibility was reduced to 3/4 mile in Spokane by blowing dust and smoke as surface winds gusted to over 45 MPH. Downslope winds steadily increased along the Rocky Mountain front. By 1615 hrs Choteau reported winds

steady at 36 to 42 MPH. The Beartop Lookout on the Gates Park Fire reported westerly winds at 20 MPH with gusts to 25. By 1700 hrs the front was on a line from about Malta-east of Bozeman-West Yellowstone. During the evening the Yellowstone area recorded winds up to 50 MPH on the Storm Creek Fire and the Clover / Mist Fire (Yellowstone National Park), 60 MPH gusts occurred on the higher peaks. Winds in the vicinity of the Clover / Mist Fire abated shortly after midnight. Gusty winds over 30 MPH had occurred in most areas of the Region and over 40 MPH at some. Afternoon temperatures were similar to the two preceding days, in the mid-80's to low 90 degree range. Lewistown recorded the high temperature for Montana at 94 degrees (Bushey 1989).

Long Range Forecast: The three to five day outlook was for cooler temperatures, higher humidities, and windy at times. Slight chance of showers would exist in northern areas of the Region. Six to ten day outlook called for temperatures to continue above normal and precipitation below normal (Bushey 1989).

September 7 (Julian Date 251)

Calculated 1-Hour Fuel Moisture under unburned canopy for area in the southeast corner of section 8 (elevation 3,640 feet msl) ranged from 7.0 to 9.0% between 2400 - 0800 hrs, Probability of Ignition dropped from 40 to 30%, Fuel level temperature declined from 66F to 61F. Shade factor was 100% due to forest canopy and shading from the upwind smoke convection column. The fire passed through this area at approximately 0630 hrs when the fuel moisture was about 8.3%.

0053 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 19 MPH, north-northwest
Maximum Wind Gust and Direction: 38 MPH, north
Temperature: 58F
Relative Humidity: 40%
1-Hour and 10-Hour Fuel Moisture: 9% and 10%

0153 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 12 MPH, north-northwest
Maximum Wind Gust and Direction: 37 MPH, north
Temperature: 56F
Relative Humidity: 46%
1-Hour and 10-Hour Fuel Moisture: 10% and 10%

0253 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 12 MPH, north-northwest
Maximum Wind Gust and Direction: 27 MPH, north
Temperature: 54F
Relative Humidity: 48%
1-Hour and 10-Hour Fuel Moisture: 10% and 11%

0353 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 12 MPH, north-northeast
Maximum Wind Gust and Direction: 26 MPH, north
Temperature: 53F
Relative Humidity: 50%
1-Hour and 10-Hour Fuel Moisture: 11% and 11%

0453 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 8 MPH, north-northeast
Maximum Wind Gust and Direction: 25 MPH, north-northeast
Temperature: 51F
Relative Humidity: 47%
1-Hour and 10-Hour Fuel Moisture: 11% and 12%

0553 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 5 MPH, north-northwest
Maximum Wind Gust and Direction: 20 MPH, northwest
Temperature: 49F
Relative Humidity: 55%
1-Hour and 10-Hour Fuel Moisture: 12% and 12%

1-Hour Fuel Moisture calculated for unburned conditions in and around the fire origin site indicated that moisture levels climbed above 12% during the morning hours (approximately 0600 - 1200 hrs, peak moisture level attained at 1000 hrs of 12.9%) with Probability of Ignition dropping to 20%.

0653 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 9 MPH, north
Maximum Wind Gust and Direction: 16 MPH, north-northeast
Temperature: 49F
Relative Humidity: 59%
1-Hour and 10-Hour Fuel Moisture: 13% and 12%

0753 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 10 MPH, north-northwest
Maximum Wind Gust and Direction: 22 MPH, north
Temperature: 49F
Relative Humidity: 55%
1-Hour and 10-Hour Fuel Moisture: 11% and 13%

Fire very active throughout the night and by daylight had crossed the North Fork Road in sections 7, 8, and 17 but had not yet crossed the river. By 0800 hrs several houses were within the fire perimeter but none have been confirmed destroyed (Loving 1988).

0800 hrs Missoula Fire Weather Office Morning Forecast - ...Cancel Red Flag...Windy weather general over area and well advertised...
Discussion: Strong pressure gradient today with westerly jet stream over northern part of Region producing gusty westerly winds...some cooling. Dewpoints still very low over southern part of Region while up slightly in north, thus still very dry in south with humidity up some northern zones. Airmass still dry and stable Thursday with lessening pressure gradient but still brisk westerly flow pattern across northern zones.

Zone 104: Today...
Weather: Partly cloudy.
LAL: 1 CWR: zero
Maximum Temperatures: 60s and 70s.
Minimum Humidities: 25 to 35%.
Surface Winds: SW to W 10 to 15 with 15 to 30 gusty more exposed areas.
Free Air Winds: West 25.

Tonight...
Weather: Clear to partly cloudy.
LAL: 1 CWR: zero
Minimum Temperatures: 40 with 30s high country.
Maximum Humidities: 70 to 90% bottoms...40 to 60 slopes/ridges.
Surface Winds: SW to NW 5 to 10 with 10 to 20 higher exposed areas.
Free Winds: West 20.
Tomorrow...Thursday.
Weather: Sunny.
LAL: 1 CWR: zero
Maximum Temperatures: 65 to 75.
Minimum Humidities: 15 to 25%
Surface Winds: W to N 3 to 8 with 8 to 15 gusty exposed areas afternoon.
Free Winds: West 20.
3 to 5 Day Outlook...Friday through Sunday.
Warm and dry at first, turning cooler with chance of showers or areas of rain of the weekend. Highs 70s and 80s Friday, cooling to 50s and 60s. Lows 30s and 40s.
Smoke Dispersion Forecast....
Dispersion good today with gusty west winds. Fair tonight and Thursday.

0830 hrs. -- **Fire Behavior Warning** -- RICO Fire Behavior Service Center

Continued strong winds and very dry fuel will contribute to extreme and erratic fire behavior through-out the day. Lets be alert and not get into any unnecessarily dangerous positions.

Strong west-northwest winds continue to blow across the Region. Wind profiles from 0600 today show various "bumps" and "indentations" but not the protrusion which would be expected with a reverse wind profile. A reverse wind profile did appear on last nights Spokane sounding and a special fire behavior warning was issued on that feature. The important fact gleamed on todays sounding is wide spread strong winds with exceedingly high velocities starting at the 10,000-12,000' elevations. Spokane has velocities of 105 mph at approximately 23,000'.

Moderate fuel moisture recovery was only experienced last night over the far western portion of the Region in northern Idaho and western Montana. The rest of the Region and Yellowstone National Park had poor recovery with fuel moisture values continuing to decline last night over much of eastern Montana.

Expect continued extreme burning conditions to continue through the day with the strong possibility of very erratic and extreme fire behavior. Dropping temperatures and rising humidities late today will help, but those fuels are very dry and a lag time will exist. Heavy fuels will not show any response until precipitation is received. Pay close attention to your local, or incident fire weather forecaster. (Chuck Bushey, FBA, Fire Behavior Service Center, RICO Planning Section)

0853 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 8 MPH, north-northwest
Maximum Wind Gust and Direction: 26 MPH, north-northwest
Temperature: 52F
Relative Humidity: 53%
1-Hour and 10-Hour Fuel Moisture: 10% and 13%

0953 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 11 MPH, northwest
Maximum Wind Gust and Direction: 26 MPH, northwest
Temperature: 54F
Relative Humidity: 49%
1-Hour and 10-Hour Fuel Moisture: 9% and 13%

1053 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 7 MPH, north-northeast
Maximum Wind Gust and Direction: 25 MPH, north-northeast
Temperature: 56F
Relative Humidity: 45%
1-Hour and 10-Hour Fuel Moisture: 8% and 12%

1153 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 8 MPH, north
Maximum Wind Gust and Direction: 26 MPH, north-northeast
Temperature: 59F
Relative Humidity: 42%
1-Hour and 10-Hour Fuel Moisture: 7% and 11%

1253 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 9 MPH, north
Maximum Wind Gust and Direction: 25 MPH, north
Temperature: 60F
Relative Humidity: 38%
1-Hour and 10-Hour Fuel Moisture: 6% and 11%

At 1300 hrs received word that spot fires are starting to get across the river in section 8 above the River Campground. Spots took off immediately forcing personnel to pull back. No opportunity for air support due to the wind and smoke. Park personnel report that all are safe although one crew is cut off on the north side of the fire run. Air attack advises that current wind direction will carry fire 1 to 1-1/2 miles north of the Polebridge Ranger Station and is in no immediate threat (Loving 1988).

1353 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 10 MPH, north-northwest
Maximum Wind Gust and Direction: 37 MPH, north
Temperature: 56F
Relative Humidity: 37%
1-Hour and 10-Hour Fuel Moisture: 7% and 10%

Calculated 1-Hour Fuel Moisture for the heavily forested riparian zone at the mouth of Red Meadow Creek on the east side of the North Fork of the Flathead River (elevation 3,600 feet msl) was 7.6% from 1200-1400 hrs with a Probability of Ignition of 40%. Fuel level temperature under an unburned canopy in this vicinity was 62F. Shade factor was 100% due to forest canopy and heavy smoke from ther fire upwind. The fire passed through this zone at about 1300 hrs. (Behave Moisture Module)

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	No data, personnel preoccupied with approaching fire.											
W. Glacier	80F	23%	9	0.00	112%	85%	4%	8%	15%	15%	39	50
S. Bear LO	48F	44%	16	0.00	70%	35%	7%	5%	8%	10%	65	87
S. Bear RS	63F	30%	15	0.00	100%	63%	5%	4%	11%	14%	49	73
H.Horse RS	64F	34%	25	0.00	90%	38%	7%	7%	11%	13%	51	97

Within 8 minutes of crossing the river the fire had run approximately 3/4's of a mile. This happened so quickly that the aerial patrol had made a loop across the river and above the park and reported no fire, then was flying west back over the fire when Cyclone Peak Lookout reported the fire in the Park. By the time the aerial patrol turned around and was again over the fire front it had already traveled the above distance. Flame lengths through the fescue grasslands were estimated to be between 6-8 feet, and when the fire reached the lodgepole pine the tree canopies were quickly involved. (Mary Peterson, Interview)

Logging Unit 2 had received spots on the 6th, but mostly burned on the 7th (Clarence R. "Bud" Anderburg). Winds from the northwest caused these spot fires to expand and burn upslope in to areas burned the previous day.

1453 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 12 MPH, north
Maximum Wind Gust and Direction: 27 MPH, north-northeast
Temperature: 55F
Relative Humidity: 41%
1-Hour and 10-Hour Fuel Moisture: 8% and 10%

Calculated 1-Hour Fuel Moisture for the "Big Prairie" grassland on the east side of the North Fork of the Flathead River (elevation 3,600 feet msl) was estimated to range from 6.5 to 8.4% between 1200-2400 hrs. Probability of Ignition during this period dropped from 40 to 30% and fuel level temperatures declined from 62F to 49F. Shade factor was 100% due to the upwind smoke convection column and heavy atmospheric haze. The fire passed through much of this zone between 1300-1400 hrs when the 1-Hour Fuel Moisture level was 6.5% with flanking fires burning during the later time periods. By 1600 hrs the fire had traveled about 2 miles and was climbing above the 3,600 feet msl elevation, 1-Hour Fuel Moisture levels during this period were about 7.0% with a Probability of Ignition of 40%.

As the fire entered the lodgepole pine timber east of Big Prairie it began to enter areas of heavy, jack-strawed, dead lodgepole pine with standing dead lodgepole pine and a spruce and subalpine fir understory with crown heights of 30-40 feet under the remaining live lodgepole pine. The fire began to "blowup" with a prominent convection column (see photos taken by Harold and Rachael Sweet from their Cabin, southwest 1/4, section 5 toward Polebridge Ranger Station, volume 1).

1530 hrs Missoula Fire Weather Afternoon Forecast -

Discussion: The low pressure system that brought the winds today and last night is on its way east, and a weak high pressure will be over us for the next few days. Looking toward this weekend, the pattern will change as a low from the Gulf og Alaska moves into the Pacific Northwest. Temps much cooler...humidity up and a chance of showers in the muntains mostly.

All Zones:

Tonight...

Weather: Clearing, partly cloudy this evening. some areas of smoke.
LAL: 1 CWR: zero
Minimum Temperatures: quite cool...lows mainly in the 30s.
Maximum Humidities: humidity up most areas...max 50-60%
Surface Winds: westerly 8-15 MPH with stronger gusts most areas this evening... decreasing late tonight.

Tomorrow...

Weather: Sunny...some areas of smoke.
LAL: 1 CWR: zero
Maximum Temperatures: still quite cool...upper 60s to middle 70s.
Minimum Humidities: 20-30%
Surface Winds: west to southwest 5-10 MPH with gusts to 15 MPH
Free Winds: west 20 MPH

Outlook for Friday...

Mostly sunny with some areas of smoke. Temps up about 5 degrees. Humidity down about 5%. Westerly winds 5-10 MPH.

3 to 5 Day Outlook...Saturday through Monday...

Much cooler and more humid. Chance of showers, especially northern Mountains. Winds southwest. Min temps in the 30s, max temps dropping into the 40s to mid 50s by Monday.

Fire continued to make major runs working toward the south later in the afternoon (Loving 1988).

1553 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 11 MPH, north
Maximum Wind Gust and Direction: 35 MPH, north
Temperature: 56F
Relative Humidity: 38%
1-Hour and 10-Hour Fuel Moisture: 7% and 10%

1600 hrs. All efforts were concentrated on saving the Polebridge Ranger Station, just across the North Fork of The Flathead River and within Glacier National Park (Loving 1988).

1653 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 10 MPH, north
Maximum Wind Gust and Direction: 30 MPH, north-northeast
Temperature: 57F
Relative Humidity: 39%
1-Hour and 10-Hour Fuel Moisture: 6% and 10%

1700 hrs. The Polebridge Ranger Station was evacuated as the fire approached (Loving 1988).

1753 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 8 MPH, east
Maximum Wind Gust and Direction: 22 MPH, north-northeast
Temperature: 55F
Relative Humidity: 35%
1-Hour and 10-Hour Fuel Moisture: 6% and 9%

1853 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 8 MPH, east-northeast
Maximum Wind Gust and Direction: 27 MPH, northeast
Temperature: 51F
Relative Humidity: 36%
1-Hour and 10-Hour Fuel Moisture: 8% and 9%

1953 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 8 MPH, east
Maximum Wind Gust and Direction: 23 MPH, northeast
Temperature: 50F
Relative Humidity: 38%
1-Hour and 10-Hour Fuel Moisture: 9% and 10%

2053 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 13 MPH, east-southeast
Maximum Wind Gust and Direction: 27 MPH, east
Temperature: 49F
Relative Humidity: 39%
1-Hour and 10-Hour Fuel Moisture: 10% and 10%

Approximately 2100 hrs the fire started to burn through the community of Polebridge on the west side of the river. The fire flank had turned south with a down drainage wind shift. As the fire dropped out of the tree crowns surrounding the community it turned into a wind driven grass fire with 1-2 foot flame lengths in the mostly short grass (average height 4 inches). Areas which had been mowed or heavily grazed frequently failed to burn and the fire followed areas of ungrazed grass and stream drainages with mature overstory cottonwoods with scattered spruce, lodgepole pine, and subalpine fir reaching into the crowns. Heavy shrub and herbaceous fuel was also available in these riparian zones. Out of 100 total dwellings within the fire area, 15 were destroyed. Another 5 outbuildings were lost where dwellings were saved. Also 4 vehicles and 1 tractor were destroyed. (John Federick, Polebridge AYH Hostel Owner)

2153 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 9 MPH, east
Maximum Wind Gust and Direction: 28 MPH, east
Temperature: 47F
Relative Humidity: 35%
1-Hour and 10-Hour Fuel Moisture: 9% and 10%

During the evening and second night of the fire, flame lengths were reported to be 200-300 feet above the tree tops, with exploding gas balls within the convection column inside the Park. During this fire run the total tree canopy was involved in the flaming front. Tree tops were again observed to be torn off and sent flaming through the air to start new spot fires.

Between 2100-2200 hrs the wind velocity eased and the fire behavior became noticably reduced. (Mary Peterson, Interview)

2200 - 2400 hrs. Division Group Humpries has observed a fire storm in the Polebridge community, observed flame heights of over 150 feet. (Pat Velasco, Incident FBA)

2253 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 2 MPH, south
Maximum Wind Gust and Direction: 27 MPH, east-southeast
Temperature: 45F
Relative Humidity: 34%
1-Hour and 10-Hour Fuel Moisture: 9% and 11%

2353 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 3 MPH, east
Maximum Wind Gust and Direction: 10 MPH, south-southeast
Temperature: 44F
Relative Humidity: 36%
1-Hour and 10-Hour Fuel Moisture: 10% and 11%

Regional Weather: Red Flag Warnings remained in effect for eastern Montana, particularly the southern portions and the Greater Yellowstone area for gusty winds and low humidities.

Winds continuing throughout the night and kept temperatures in the 50's and low 60's across most of the Region as a dry cold front passed through Montana from the northwest during the early morning hours. At 0300 hrs on the Canyon Creek Fire in a safety zone were 110 persons safely were watching the fire a temperature of 75 degrees, 15% relative humidity, and 40 MPH westerly winds were reported. Skies across the Region were generally partly cloudy to mostly sunny. Smoke from the forest fires reduced visibility across the southern and western portions of the Region. Several stations reported visibility of 2 miles or less during the morning, but with improvement by the afternoon. Inversions in the Yellowstone area lifted in the late morning. The 0600 hrs Spokane radiosonde still indicated a strong low level reverse wind profile with upper level winds over 15,000' being between 70 and 105 MPH. The only rainfall experienced were a few sprinkles across the hi-line and north into Canada. Glasgow reported .04" of rain. By 1200 hrs the cold front had exited from the Region. Afternoon temperatures were mostly in the 70's behind the front. Twenty to 40 MPH west winds were common with Glasgow reporting the strongest gusts at 48 MPH and Great Falls reaching gust to 44 MPH. Afternoon and evening winds in the Yellowstone area blew from the southwest to west at 15 to 30 MPH. Gusts to 40 to 50 MPH were reported on the Storm Creek and Clover / Mist Fires. High temperatures in these areas ranged from 75 to 85 degrees, and low humidities ranged from 8 to 18% (Bushey 1989).

September 8 (Julian Date 252)

Temperatures dropped significantly during early morning hours with a deep inversion setting in (Loving 1988).

0053 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 1 MPH, east- southeast
Maximum Wind Gust and Direction: 4 MPH, west
Temperature: 42F
Relative Humidity: 38%
1-Hour and 10-Hour Fuel Moisture: 11% and 11%

0153 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 2 MPH, north-northwest
Maximum Wind Gust and Direction: 7 MPH, east-northeast
Temperature: 41F
Relative Humidity: 38%
1-Hour and 10-Hour Fuel Moisture: 11% and 12%

0253 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 0 MPH, east-northeast
Maximum Wind Gust and Direction: 6 MPH, north-northwest
Temperature: 40F
Relative Humidity: 37%
1-Hour and 10-Hour Fuel Moisture: 10% and 12%

0353 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 1 MPH, east-southeast
Maximum Wind Gust and Direction: 3 MPH, southwest
Temperature: 40F
Relative Humidity: 38%
1-Hour and 10-Hour Fuel Moisture: 11% and 12%

0453 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 2 MPH, southeast
Maximum Wind Gust and Direction: 4 MPH, northwest
Temperature: 40F
Relative Humidity: 37%
1-Hour and 10-Hour Fuel Moisture: 11% and 12%

0553 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 0 MPH, north
Maximum Wind Gust and Direction: 5 MPH, south
Temperature: 39F
Relative Humidity: 36%
1-Hour and 10-Hour Fuel Moisture: 10% and 13%

0653 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 2 MPH, south
Maximum Wind Gust and Direction: No Data
Temperature: 39F
Relative Humidity: 35%
1-Hour and 10-Hour Fuel Moisture: 10% and 13%

0700 hrs. Weather at Polebridge; 3,500 msl, DB 28, WB 32, calm, heavily smoked in. (Pat Velasco, Incident FBA)

0753 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 1 MPH, west-northwest
Maximum Wind Gust and Direction: No Data
Temperature: 40F
Relative Humidity: 36%
1-Hour and 10-Hour Fuel Moisture: 9% and 12%

0800 hrs. Weather; 3,800 msl, DB 38F, WB 32F, wind north 0-2 MPH. (Pat Velasco, Incident FBA)

0830 Missoula Fire Weather Morning Forecast -

Discussion: High pressure over the Region at the surface and jet stream retreating north again put us under much lighter wind flow pattern today and Friday. Airmass very..very dry as noted by low dew points everywhere. In the future... approaching low pressure trough from the Pacific..hinting at frontal passage Saturday..thus wind should pickup in very dry airmass Saturday. Stay tuned for change to cool, showery weather advertised on 3-5 day forecast. A bit far off yet to determine details.

All Zones:

Today...
Weather: Sunny
LAL: 1 CWR: zero
Maximum Temperatures: 60s to 70s with few 80s in souther zones.
Minimum Humidities: 15 to 25%.
Surface Winds: Variable 2 to 8 MPH...west 10 to 15 ridges/upper slopes..occasional gusts 25 east slopes Rockies and ridges above 7,000 feet.
Free Winds: w to nw 15.

Tonight...
Weather: Chilly...clear...locally smokey.
LAL: 1 CWR: zero
Mimumum Temperatures: 30s to 40s with 20s high elevations valleys.
Maximum Humidities: Mountain areas 70 to 90% bottoms...35 to 50% slopes/ridges. Plains...east slope Rockies 35 to 55%.
Surface Winds: Mostly normal light terrain winds 0 to 5...ridge winds w to n 8 to 15.
Free Winds: w to sw 15,

Tomorrow...
Weather: Sunny and locally smokey.
LAL: 1 CWR: zero
Maximum Temperatures: 70 to 85
Minimum Humidities: 15 to 25%
Surface Winds: Variable 0 to 10.. afternoon winds little stronger south to southwest...15 gusty exposed areas...likely picking up at times on east slopes.
Free Air Winds: SW to W 15.

3-5 Day Outlook...Saturday through Monday...
Warm..dry and windy Saturday..cooling with showers developing Sunday and Monday and chance some snow at higher elevations. High 70s Saturday cooling into 50s by Monday. Lows cooling to 20s and 30s with 30s and 40s south.

6-10 Day Outlook...Tuesday September 13 through Saturday September

17...
Temps: below normal Precip: near to above normal
Smoke Dispersion Forecast....
Dispersion fair today with mixing to 7 or 8,000' and transport winds variable 5 to 15. Dispersion poor tonight..fair to poor Friday.

0830 hrs. RICO Fire Behavior Service Center -

One hour fuel moisture recovery last night was much better for the majority of the Region than it has been for quite some time. The Nez Perce, Clearwater, and portions of the Beaverhead and Gallatin forests had good recovery; while most of the rest of the Montana had moderate recovery. The plains south of Billings, MT and around West Yellowstone NP, the southern portions of the Gallatin and Beaverhead forests then into the Salmon River break country of Idaho had poor recovery. Low afternoon 1-hr fuel moisture today for western Montana will be in the 3-6% range for sunny areas with a Probability of Ignition of 50 - 80%, areas under smoke, clouds, shade, etc. will have low 1-hr moistures of 6 - 8% with a P. of I. of 40- 50%. An improvement over the 2 - 5 % 1-hr values of the previous week.

Temperature inversions were present this morning in the mountain valleys with smoke being caught in areas of light wind (been awhile since I could say light wind). A subsidence inversion is still indicated over the northern portions of the Region at the elevations of 6,000' in Spokane and 10,500' in Great Falls. Care should be exercised for possible thermal belt conditions associated with fires at these higher elevations. The current elevation of the upper freezing zone is approximately 10,000' at Great Falls, 11,000' above Spokane, and 15,000" above Boise. Wind speeds gradually increase with elevation at Boise with stronger winds of 25-30 MPH between 9,000'-21,000'. At Spokane 25 MPH winds are at 10,000' and gradually increase to 50 MPH at 19,000'. And above Great Falls there are 25 MPH winds at 10,000', 30 MPH at 12,000', 40 MPH at 14,000', 50 MPH above 19,000'. Strong surface winds are predicted to continue for the Yellowstone ecosystem throughout the coming weekend.

For those in the Northern Region, I have been receiving numerous inquires concerning the possibility of precipitation this weekend. The forecast does indicate showers with the potential for snow at the higher elevations. However, these showers will not cover the entire area and will only be locally heavy. We will need more than this for the "end of the season event." (Chuck Bushey, FBA, Fire Behavior Service Center, RICO Planning)

0853 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 2 MPH, south
Maximum Wind Gust and Direction: No Data
Temperature: 45F
Relative Humidity: 37%
1-Hour and 10-Hour Fuel Moisture: 8% and 12%

0953 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 1 MPH, east-northeast
Maximum Wind Gust and Direction: No Data
Temperature: 49F
Relative Humidity: 35%
1-Hour and 10-Hour Fuel Moisture: 8% and 12%

1053 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 4 MPH, south
Maximum Wind Gust and Direction: No Data
Temperature: 50F
Relative Humidity: 37%
1-Hour and 10-Hour Fuel Moisture: 7% and 11%

1100 hrs. Weather; inversion lifted higher elevations. (Pat Velasco, Incident FBA)

1153 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 5 MPH, north-northwest
Maximum Wind Gust and Direction: No Data
Temperature: 59F
Relative Humidity: 34%
1-Hour and 10-Hour Fuel Moisture: 6% and 10%

1200 hrs. Weather; DB 57F, WB 46F, RH 48, wind southwest 3 MPH. (Pat Velasco, Incident FBA)

1253 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 5 MPH, northeast
Maximum Wind Gust and Direction: No Data
Temperature: 62F
Relative Humidity: 25%
1-Hour and 10-Hour Fuel Moisture: 5% and 10%

1300 hrs. Weather; inversion lifted lower elevations. (Pat Velasco, Incident FBA)

1330 hrs. High intensity fire behavior begining all areas. Fire behavior is becoming extreme. All divisions are reporting spotting, torching and crowning. High convective column is begining. Winds were southerly variable to west. (Pat Velasco, Incident FBA)

Fire became very active as inversion lifted (Loving 1988).

1353 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 5 MPH, north
Maximum Wind Gust and Direction: No Data
Temperature: 64F
Relative Humidity: 23%
1-Hour and 10-Hour Fuel Moisture: 4% and 9%

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	No data, Ranger Station abandoned.											
W. Glacier	75F	24%	9	0.00	112%	85%	5%	8%	15%	15%	39	50
S. Bear LO	--F	29%	--	0.00	70%	35%	5%	5%	10%	10%	64	72
S. Bear RS	--F	24%	--	0.00	100%	63%	4%	4%	12%	14%	48	58
H.Horse RS	--F	19%	--	0.00	91%	39%	4%	7%	12%	13%	51	72

1400 hrs. Weather; DB 57F, WB 46F, RH 29, wind southeast 8 MPH, gust 13. (Pat Velasco, Incident FBA)

1400 hrs, spotting and torching all areas. (Pat Velasco, Incident FBA)

Approximately 1400 hrs. Several columns became visible from camp. Wind shifted more to south-southwest this afternoon causing fire to burn into itself in many places (Loving 1988).

1453 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 11 MPH, north
Maximum Wind Gust and Direction: No Data
Temperature: 63F
Relative Humidity: 23%
1-Hour and 10-Hour Fuel Moisture: 4% and 8%

1400-1500 hrs. Division A is reporting difficulty holding the line. Numerous spots. High intensity fire behavior Division C is reporting numerous spots. (Pat Velasco, Incident FBA)

1530 hrs. Weather at Polebridge; DB 73F, WB 52F, RH 22%, wind southeast 2 MPH, gusts to 12. (Pat Velasco, Incident FBA)

1530 Missoula Fire Weather Afternoon Forecast -

Discussion: High pressure will be over the area Friday ahead of a weather system approaching from the north. Some moisture is expected with this system, but not a lot. The front will be hard to track again, but feel late Friday night will see it into the Idaho panhandle. Concern is for more southwest and west winds with this system this weekend.

North Half 104...
Tonight...
Weather: Smokey, but fair
LAL: 1 CWR: zero
Minimum Temperatures: cold...Mainly 30s, although some upper teens and 20s mountain vallleys.
Maximum Humidities: Recovery good most areas...80-100% cpldest areas, otherwise near 75%
Surface Winds: Southwest on ridges..3-7 MPH, otherwise downslope 0-4 MPH.
Tomorrow...
Weather: Smokey with some high clouds.
LAL: 1 CWR: zero
Maximum Temperatures: Warmer...highs 68-77.
Minimum Humidities: 15-20%
Surface Winds: Southwest on ridges..3-7 MPH, otherwise downslope 0-4 MPH.
Free Winds: West 15 MPH
Outlook for tomorrow...Saturday
Partly cloudy. Slight chance of mountain showers. Breezy with increasing southest winds. Temps about the same...humidity up some.
3-5 Day Outlook...Sunday through Tuesday ...
Chance of showers mainly Sunday and Monday...Otherwise variable cloudiness and colder. Humidity up. wind southewst to west 10-15 MPH and gusty.

1553 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 10 MPH, north
Maximum Wind Gust and Direction: No Data
Temperature: 63F
Relative Humidity: 26%
1-Hour and 10-Hour Fuel Moisture: 5% and 8%

1653 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 6 MPH, north
Maximum Wind Gust and Direction: No Data
Temperature: 65F
Relative Humidity: 27%
1-Hour and 10-Hour Fuel Moisture: 5% and 7%

Nightshift Fire Weather Forecast for the Red Bench Fire:
Discussion: Upper level ridge moving over the fire tonight. Flow aloft westerly and moderate. Surface pressure gradient weak...allowing local effects to predominate. Surface inversion developing and being reinforced by weak subsidense inversion.
Forecast: **all winds 20'** Smoke setting in valleys tonight otherwise fair. Min temps 28-33 valleys and 33-40 ridges. Max RH 88-95% valleys and 78-88% ridges. Winds light and variable except downslope-downvalley 3-7 MPH in areas subject to air drainage. LAL 1.

1500-2400 hrs. During this time period and continuing the fire experienced extreme fire behavior with extremely high rates-of-spread 100 to 120 chains per hour. Flame heights up to 300 feet were reported, along with a very large convection column, and spotting up to 1 1/2 miles. Destroyed many houses, buildings, bridges, etc. (Pat Velasco, Incident FBA)

A major reburn of the fire origin occurred (Red Bench Fire Case Report: File Designation:5300, B. Hurd). The fire developed from spot and flanking fire below Logging Unit 2 and above the road. The fire swept uphill, burning the unburnt leave strip between Logging Units 2 and 3 as well as burning approximately the eastern 2/3's of the unburnt Unit 3. The fire continued burning upslope and to the SE moving to the ridge top as well as reburning a portion of the area previously burned on September 6th (including the fire's origin location). (Interview with Clarence R. "Bud" Anderburg)

1753 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 11 MPH, north-northwest
Maximum Wind Gust and Direction: No Data
Temperature: 62F
Relative Humidity: 28%
1-Hour and 10-Hour Fuel Moisture: 6% and 7%

1853 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 11 MPH, north-northwest
Maximum Wind Gust and Direction: No Data
Temperature: 58F
Relative Humidity: 29%
1-Hour and 10-Hour Fuel Moisture: 7% and 7%

1953 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 3 MPH, north-northwest
Maximum Wind Gust and Direction: No Data
Temperature: 55F
Relative Humidity: 32%
1-Hour and 10-Hour Fuel Moisture: 8% and 8%

2000 hrs. Weather at DP 102; DB 58F, WB 49F, RH 48%, wind southwest 2 MPH. (Pat Velasco, Incident FBA)

2053 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 3 MPH, northwest
Maximum Wind Gust and Direction: No Data
Temperature: 54F
Relative Humidity: 36%
1-Hour and 10-Hour Fuel Moisture: 9% and 9%

2153 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 5 MPH, north-northwest
Maximum Wind Gust and Direction: No Data
Temperature: 54F
Relative Humidity: 40%
1-Hour and 10-Hour Fuel Moisture: 9% and 9%

Inversion developed early this night and by 2200 very little fire activity visible from camp. Fire remained relatively calm throughout the night (Loving 1988).

2253 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 1 MPH, north
Maximum Wind Gust and Direction: No Data
Temperature: 53F
Relative Humidity: 41%
1-Hour and 10-Hour Fuel Moisture: 10% and 10%

2353 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 3 MPH, north-northwest
Maximum Wind Gust and Direction: No Data
Temperature: 52F
Relative Humidity: 41%
1-Hour and 10-Hour Fuel Moisture: 10% and 11%

Regional Weather: High pressure was moving into Montana from the west bringing generally clear skies and sunny weather across the state as the jetstream retreated to the north. Some high clouds still lingered in the northeast during the morning hours, where thunderstorms had occurred during the night. Winds diminished during the night and by 0500 hrs were generally less than 10 MPH. Smoke was mainly confined to the southwestern portion of the Region in the morning. Visibility was reported to be less than 2 miles at West Yellowstone, Dillon , Monida, and Cutbank. These areas of smoke gave way to mostly sunny skies in the late morning and early afternoon as light winds became more southwesterly with 10 to 20 MPH speeds and gusts to 25 MPH. Morning temperatures were quite a bit cooler following the frontal passage. Readings were in the 30's in parts of the west and north, with mostly 40's

throughout the rest of the Region. At 0500 hrs temperatures ranged from 34 degrees at Kalispell to 51 at Billings. Afternoon temperatures were mainly in the 70's. High temperature in Yellowstone National Park ranged from the mid-60's to the mid-70's with minimum humidity readings of 10 to 20%. Winds remained out of the west and increased to 10 to 25 MPH east of the continental divide, with Livingston reaching gusts of 36 MPH (Bushey 1989).

Long Range Forecast: Three to five day forecast indicated that warm and dry conditions on the 10th would start to change to cooler with showers on the 11th. There would be a chance of snow at the higher elevations in northern Idaho and western Montana. High temperatures on the 11th were expected to reach the 50's in the west and 60's in the east. The six to ten day outlook expected below normal temperatures and near normal to above normal precipitation (Bushey 1989).

September 9 (Julian Date 253)

0600 hrs. Weather; DB 34F, RH 100%, wind calm, heavy inversion.

0553 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 2 MPH, northwest
Maximum Wind Gust and Direction: No data
Temperature: 47F
Relative Humidity: 45%
1-Hour and 10-Hour Fuel Moisture: 11% and 13%

0653 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 3 MPH, northwest
Maximum Wind Gust and Direction: 6 MPH, north-northwest
Temperature: 47F
Relative Humidity: 48%
1-Hour and 10-Hour Fuel Moisture: 11% and 13%

0753 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 4 MPH, west-northwest
Maximum Wind Gust and Direction: 8 MPH, west-northwest
Temperature: 48F
Relative Humidity: 48%
1-Hour and 10-Hour Fuel Moisture: 9% and 13%

0800 hrs Missoula Fire Weather Office Morning Forecast - ...Red Flag watch for tonight and Saturday...Frontal Passage and Wind...

Discussion: Frontal system is forecast to develop in leading edge of upper level trough of low pressure and cross the Region tonight and Saturday. Southwest to west wind will increase higher elevations tonight with much cooler air from the north will move southward and over the Region Saturday afternoon into Sunday. Not much moisture indicated with this development at this time.
Zone 104:

Today...
Weather: Some high cloudiness and areas of smoke.
LAL: 1 CWR: zero
Maximum Temperatures: From 60s high elevations to 70s and low 80s lower elevations.

Minimum Humidities: 15 to 25%.
Surface Winds: SW to NW 3 to 6 becoming 15 to 20 higher exposed areas.
Free Air Winds: SW to W 20 northern zones.

Tonight...

Weather: Variable high and middle cloudiness, chance few light showers northern zones.
LAL: 1 CWR: zero
Mimumum Temperatures: 40s and low 50s...30s higher elevations.
Maximum Humidities: 55 to 70%...30 to 40 ridges/slopes.
Surface Winds: SW to NW 5 to 15 gusty exposed areas with 15 to 30 on high ridges and exposed slopes.
Free Winds: SW to W 20 to 35.

Tomorrow...

Weather: Variable cloudiness. Chance of few light showers.
LAL: 1 CWR: zero
Maximum Temperatures: Cooling from the north, highs 60s north to 70s southern zones.
Minimum Humidities: Likely rising in northern zones from 25 to 35% north to 15 to 20% south.
Surface Winds: SW to NW 10 to 20 with 20 to 40 and gusty more exposed areas.
Free Winds: SW to W 25 to 35.

3 to 5 Day Outlook...Sunday through Tuesday...

Much cooler with a chance of scattered showers Sunday and gusty Northwest winds in exposed areas. Dry and Breezy on Monday and Tuesday with slow warming. Highs 40s high elevations and 55 to 65 valleys Sunday. Warming to 65 to 75 by Tuesday. Lows 30s and low 40s with teens and 20s in mountain areas.

Smoke Dispersion Forecast....

Poor until Monday many areas light winds becoming fair afternoon with good higher elevations. Dispersion becoming mostly good late tonight through Saturday due to increasing winds.

0815 hrs. Weather; DB 43F, WB 38F, RH 63%, wind southwest at 1 MPH.

0853 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 4 MPH, northwest
Maximum Wind Gust and Direction: 7 MPH, north-northwest
Temperature: 51F
Relative Humidity: 50%
1-Hour and 10-Hour Fuel Moisture: 9% and 13%

0900 hrs. Fire is active at 5,600 feet msl southerly exposure.

0900 hrs. Word received of a larch snag which fell on a crew, one crew member was fatally injured and several others received lessor injuries. Accident involved five individuals from the Coeur d' Alene #9 crew (Loving 1988).

0953 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 6 MPH, west-northwest
Maximum Wind Gust and Direction: 11 MPH, west
Temperature: 56F
Relative Humidity: 47%
1-Hour and 10-Hour Fuel Moisture: 7% and 12%

1053 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 5 MPH, west-northwest
Maximum Wind Gust and Direction: 13 MPH, northwest
Temperature: 59F
Relative Humidity: 41%
1-Hour and 10-Hour Fuel Moisture: 7% and 11%

1153 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 2 MPH, south-southwest
Maximum Wind Gust and Direction: 11 MPH, west-northwest
Temperature: 60F
Relative Humidity: 38%
1-Hour and 10-Hour Fuel Moisture: 7% and 11%

1253 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 6 MPH, northwest
Maximum Wind Gust and Direction: 16 MPH, west-northwest
Temperature: 64F
Relative Humidity: 39%
1-Hour and 10-Hour Fuel Moisture: 7% and 11%

1353 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 5 MPH, northeast
Maximum Wind Gust and Direction: 25 MPH, northwest
Temperature: 62F
Relative Humidity: 36%
1-Hour and 10-Hour Fuel Moisture: 7% and 10%

1350 hrs. Another injury occurred from falling snags. Injuried crewman is on Sierra National Forest E-13 and had a broken collar bone (Loving 1988).

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	No data, Ranger Station abandoned.											
W. Glacier	No data											
S. Bear LO	65F	31%	9	0.00	70%	35%	6%	5%	10%	10%	64	69
S. Bear RS	78F	20%	12	0.00	100%	63%	4%	4%	13%	14%	48	67
H.Horse RS	68F	30%	2	0.00	91%	39%	7%	8%	13%	13%	48	41

1416 hrs. Weather; DB 65F, WB 55F, RH 52%, wind northwest at 4 MPH, fine fuel moisture 8%

1443 hrs. Weather at river 3,800 feet msl; DB 75F, WB 59F, RH 38%, wind west 2-4 MPH, sun is breaking through

1445 hrs. Weather; DB 75F, WB 54F, RH 25%, wind west 3-4 mph gusts to 7. Erratic fire behavior all areas. Division A has west, Division B has northwest winds, Park side - north line has a south wind. All Divisions are active.

1453 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 9 MPH, west-northwest
Maximum Wind Gust and Direction: 17 MPH, northwest
Temperature: 62F
Relative Humidity: 36%
1-Hour and 10-Hour Fuel Moisture: 7% and 10%

1500 hrs. Weather at Polebridge; DB 74F, WB 56F, RH 44%, wind south-southwest 0-2 MPH gusts to 7, FFM 7-8%, inversion has lifted

1535 hrs. Weather at Camp; DB 75F, WB 47F, RH 56%, wind south 2-3 MPH gusts to 9, FFM 8% (ridges and slopes probably 1-hr 6%, 10-hr 7%, 100-hr 9%)

1553 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 7 MPH, east-northeast
Maximum Wind Gust and Direction: 16 MPH, west-northwest
Temperature: 65F
Relative Humidity: 36%
1-Hour and 10-Hour Fuel Moisture: 6% and 10%

1653 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 5 MPH, north-northeast
Maximum Wind Gust and Direction: 19 MPH, north
Temperature: 67F
Relative Humidity: 27%
1-Hour and 10-Hour Fuel Moisture: 5% and 9%

1753 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 8 MPH, north
Maximum Wind Gust and Direction: 17 MPH, north-northwest
Temperature: 63F
Relative Humidity: 26%
1-Hour and 10-Hour Fuel Moisture: 6% and 9%

1800 hrs. Weather at 3,850 feet msl; DB 72F, WB 54F, RH 28%, wind variable northwest 3-7 MPH gusts to 12

1853 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 9 MPH, north-northwest
Maximum Wind Gust and Direction: 20 MPH, north
Temperature: 59F
Relative Humidity: 25%
1-Hour and 10-Hour Fuel Moisture: 7% and 9%

General Message from Kalispell Dispatch; Red Flag Warning
Frontal passage & wind expected tonight, winds southwest - south tonite; southwest - northwest.
Saturday. Cooler airmass Saturday and Sunday.
Today: Highs 60s-70s, Humidity 15 -25%, winds southeast to 15 on ridges
Tonite: Minimum temps 40s-50s, 30s @ elevation; Humidity 55-70%, 30-40% higher sites, winds 5-15 gusts 15-30 MPH
Tomorrow: Cooling in 60s; Humidity up 25-35%, winds southwest - northwest 10-20 gusting to 20-40 in exposed areas.

The approaching cold front expected during the upcoming night posed danger for the east and southeast fire flanks (Rahm and Norum 1988). However, the fire remained inactive during the night as everyone braced for the expected increase in wind speeds (Loving 1988).

Regional Weather: Except for some smokey areas, skies were generally clear around Montana during the night. Great Falls reported an overcast of smoke around 10,000 feet during the morning and visibility was reduced by smoke to 1/8 mile at West Yellowstone and about 1/2 mile at Livingston. Early morning (0600 hrs) temperatures ranged from 33 at Butte to 53 at Billings. A cold front moved into western Montana during the afternoon from the northwest, bringing winds of 15 to 30 MPH. Afternoon temperatures warmed into the 70's and 80's. At 1800 hrs extremes ranged from 73 at Glasgow to 87 degrees at Dillon, Bozeman, and Belgrade. Winds were increasing by the afternoon and were 10 to 20 MPH west of the divide out of the southwest with some gusts to 30 MPH reported, and east of the divide winds were southeast at the same speeds. Red Flag Watches were issued for the night in northern Idaho and western Montana for winds associated with another frontal passage. Similar warnings were also issued for the Greater Yellowstone area. The watches were upgraded to warnings for western Montana and northern Idaho at 1845 hrs as the frontal system began to move faster than expected (Bushey 1989).

September 10 (Julian Date 254)

Weather Forecast for the Day shift:
Discussion: Red Flag Warning for winds. Upper trough axis east of the fire. Brisk northwest flow aloft...pushing a cooler airmass over the fire at the surface. The unstable airmass will allow scattered showers but most will be light. No morning inversion.
Forecast: **all winds are 20'*** Variable cloudiness with chance of showers. Probability of measureable precipitation 30%. Cooler. Max temp 58-63. Min RH 30-50%. Winds west to noorthwest 12 to 25 MPH but gusting to 40 MPH in some exposed areas. LAL 1.

0753 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 13 MPH, south-southeast
Maximum Wind Gust and Direction: 23 MPH, south-souteast
Temperature: 44F
Relative Humidity: 59%
1-Hour and 10-Hour Fuel Moisture: 11% and 12%

0809 hrs. Weather at 4,350 feet msl; DB 48F, WB 42F, RH 56%, wind south - west variable 0-2 eye level, 2-4 at 20' level.

0853 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 10 MPH, south-southeast
Maximum Wind Gust and Direction: 22 MPH, south
Temperature: 43F
Relative Humidity: 63%
1-Hour and 10-Hour Fuel Moisture: 11% and 13%

0900 Missoula Fire Weather Morning Forecast - Red Flag will be continued for northwest - north wind today.
Discussion: Pacific front moved through northern Idaho...western MT during night but warm-dry south to east wind flow still into areas east of divide. Surge of cool-more moist air carried by northerly winds should sweep south today. At upper levels.. low pressure through becoming more vigorous and picking up some moisture as airmass cools. See forecast below for details. Storm systems should start moving out of area Sunday afternoon and by Monday dry high pressure...Fall like...building into Region.

Zone 104:

Today...
Weather: Partly cloudy to cloudy. Scattered showers developing.
LAL: 1 CWR: 20%
Maximum Temperatures: 55 to 65.
Minimum Humidities: 20 to 30%, rising some during the afternoon.
Surface Winds: Becoming NW 10 to 15 with 15 to 30 gusty exposed areas.
Free Winds: SW 20 becoming NW to N 25 to 30 afternoon.

Tonight...
Weather: Mostly cloudy...showers with areas of rain/light snow high country.
LAL: 1 CWR: 20 to 30%
Mimumum Temperatures: 30s to 40s.
Maximum Humidities: 60 to 90%
Surface Winds: Northerly 10 to 15 with 15 to 30 more exposed areas.
Free Winds: NW to N 25 to 35

Tomorrow...Sunday
Weather: Cloudy. Scattered showers with occasional rain or snow over Rockies.
LAL: 1 CWR: 20%
Maximum Temperatures: 40s to 50s
Minimum Humidities: 45 to 55%
Surface Winds: NW to NE 10 to 20 gusty.
Free Air Winds: N 20 to 25.

3-5 Day Outlook...Monday through Wednesday.
Dry with a gradual warming trend. Highs 55 to 65 warming to near normal in 65 to 75 degree range by Wednesday. Diminishing winds.

6-10 Day Outlook...
Temps: near normal Precip: below normal 1

Smoke Dispersion Forecast....
With wind most areas good dispersion through Sunday.

0905 hrs. Weather at 4,000 feet msl; DB 51F, WB 44F, RH 53%, wind north 5-8

0945 hrs. Weather at Division F, 3,600 feet msl, grass covered bench; DB 50F, WB 43F, RH 48%, wind west 7 gusts to 12. Wind had shifted from the northwest.

0953 hrs. Cyclone Peak RAWS Weather -
Weather measurements between 0953 - 1253 hrs from the RAWS site were incomplete and garbled. Possible interference during satellite transmission.

Overcast and cold this AM. Winds pickup after sunrise and the clouds thicken. Light rain began about 1000 hrs. Fire is creeping around but

relatively inactive compared to previous days. There was not enough rain however to significantly raise the 1000-hr fuel moisture (Loving 1988).

1130 hrs. Weather at 3,850 feet msl; DB 57F, WB 48F, RH 48%, wind northwest 2-3 at eye level, 10-15 at 20' level

1130 hrs. Weather at Division F, 3,700 feet msl, low shrub/closed canopy lodgepole pine / spruce doghair level bench; DB 54F, WB 43F, RH 38%, wind southeast 0-3. Winds speeds greater above canopy, estimated 5-10 MPH.

1140 National Weather Service. Missoula, MT; Special Weather Statement:
In the way of some positive fire weather for a change....At 1103 AM MDT today, Missoula radar spotted some light showers in northwest Montana. These were in Lincoln, NW Lake, southern Flathead, and northern Missoula and Powell Counties. Also some weak showers were detected southwest of Helena. Light rain was falling at Spokane and at Walla Walla, Washington.

1153 hrs. Cyclone Peak RAWS records 0.02 inches of precipitation during the previous hour.

1200 hrs. Weather at 3,900 feet msl; DB 50F, WB 45F, RH 63%, wind northwest 0-2

1214 hrs. Weather at 3,900 feet msl; DB 52F, WB 45F, RH 54%, wind south (terrain effect) to east 3-4, east at 20' level

Observed Fire Behavior on Branch II, Quartz Lake trail; rate-of-spread smoldering and creeping, flame heights less than 12 inches.

1251 hrs. Weather at 3,900 feet msl; DB 51F, WB 45F, RH 58%, wind south 2-4 terrain effect.

1253 hrs. Another 0.02 inches of precipitation was measured by the Cyclone RAWS during the previous hour.

1353 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 5 MPH, east
Maximum Wind Gust and Direction: 10 MPH, south-southeast
Temperature: 38F
Relative Humidity: 94%
1-Hour Fuel Moisture: 57%
Precipitation: 0.03 inches during previous hour.

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	No data, Ranger Station abandoned.											
W. Glacier	No data											
S. Bear LO	31F	100%	4	0.16	70%	37%	27%	25%	13%	10%	0	0
S. Bear RS	43F	93%	3	0.24	105%	67%	23%	25%	15%	14%	0	0
H.Horse RS	48F	87%	1	0.14	95%	41%	21%	28%	14%	13%	0	0

1453 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 6 MPH, east-southeast
Maximum Wind Gust and Direction: 24 MPH, south-southwest
Temperature: 39F
Relative Humidity: 93%
1-Hour Fuel Moisture: 36%

1553 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 12 MPH, south
Maximum Wind Gust and Direction: 25 MPH, south-southeast
Temperature: 39F
Relative Humidity: 81%
1-Hour Fuel Moisture: 34%

1600 hrs. Weather at Division F, 3,700 feet msl,low shrub closed canopy lodgepole pine / spruce doghair on level bench; DB 48F, WB 46F, RH 87% wind north to northeast 3-5 gust to 8, estimated 10- 15 above canopy.

1653 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 11 MPH, south
Maximum Wind Gust and Direction: 30 MPH, south
Temperature: 40F
Relative Humidity: 76%
1-Hour Fuel Moisture: 23%

1700 hrs. Weather; Snow.

1724 hrs. Weather at Division A, F1 1/2, 5,000 feet msl; DB 46F, WB 40F, RH 54% wind east 0-4 gusts to 7; spot fire approximately 1/10 acre.

1746 hrs. Weather at 115RD, 5,500 feet msl; DB 41F, WB 37F, RH 63%, wind north 7-9 gusts to 14; snow at 6,000 - 6,300 feet msl.

1753 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 11 MPH, south-southeast
Maximum Wind Gust and Direction: 30 MPH, southeast
Temperature: 38F
Relative Humidity: 72%
Precipitation: 0.01 inches during the previous hour

1853 hrs. Cyclone Peak RAWS Weather -
Average Wind Speed and Direction: 13 MPH, south-southeast
Maximum Wind Gust and Direction: 34 MPH, south-southeast
Temperature: 37F
Relative Humidity: 73%

Regional Weather: The Red Flag Warnings issued the previous night remained in effect. A deep low pressure system had developed over Montana but no significant moisture appear during the night. Cold front was on a line from Malta-Great Falls at 0800 hrs and an area of upslope rain had developed in central Alberta. Cold Canadian air spilled down across the Region behind the front. The slowness of the system to evolve had allowed the moisture potential of the system to improve some. At 1103 hrs Missoula radar spotted some light, scattered showers in northwest Montana. These were in Lincoln, northwest Lake,

southern Flathead, northern Missoula, and Powell counties. Some weak showers were detected southwest of Helena. Light rain was reported to be falling at Spokane and Walla Walla, Washington. At 1300 hrs a report of heavy snow down to the 5,500 foot elevation in the Polebridge area was helping fire crews on the Red Bench Fire. By late afternoon scattered light rain showers were being reported over much of western Montana. These showers developed into locally heavy precipitation across western and central Montana. Light rain started falling in the Yellowstone area late in the day. Gusty northerly winds also developed with Glasgow reporting wind speeds over 40 MPH and several other stations with speeds between 30 to 35 MPH. At 1800 hrs temperatures ranged from 67 degrees at Miles City to 43 at both Butte and Lewistown.

September 11 (Julian Date 255)

0600 hrs. Weather; DB 41F, WB 37F, RH 71%, wind northwest 2-3

0832 hrs. Weather; Division A, DP 102, aspect north, slope 25%; DB 43F, WB 38F, RH 66, wind south 3-5 gusts to 10, fine fuel moisture 11%. Fire behavior on a spot fire; surface fire with minor torching, activity moderate, rate-of-spread 2 feet/minute , flame length 2 feet, spotting distance 2 feet, Probability of Ignition 21-50%. (Hann, Asst. FBA notes)

0900 hrs. Missoula Fire Weather Morning Forecast -

Discussion: We received some welcome precipitation over western Montana overnight. The real wetting was over and along the east slopes of the Rockies where Butte picked up over 1 inch... Helena 0.81...Great Falls 0.70... Bozeman 0.41...and Drummond 0.62. There was generally 1 tenth to 2 tenths of an inch further west to the Idaho border where the precipitation mostly ended, though we did receive reports of showers dropping 3 to 4 tenths of an inch from Hamilton west toward Grangevulle...We received reports of snow on the ground up in the Lincoln-Coopers Lake area. At 8 AM it was snowing at Butte, Dillion, Great Falls, Cutbank, Livingston, and light snow had just started at West Yellowstone.

A cold upper level low presure system centered along the southern border of Montana south of Dillion.. will move very slowly to the south the next 24 hours before weakening and moving to the east. This will continue to pump moisture up the east slopes of the Rockies today. High pressure will be building from the northwest into the area behind the low pressure system.

Zone 104:

Today...

Weather: Partly cloudy to cloudy...scattered rain/snow showers
LAL: 1 CWR: 10%
Maximum Temperatures: From 40s mountains to 50s and 60s lower elevations.
Minimum Humidities: 40 to 50% and higher.
Surface Winds: NW to NE 5 to 15 with 15-20 gusty more exposed areas.
Free Winds: Northerly 20.

Tonight...

Weather: Partly cloudy. Scattered rain/snow showers.
LAL: 1 CWR: 20%
Mimumum Temperatures: 20s and 30s higher elevations, 30s and 40s lowland.
Maximum Humidities: 70% and higher.
Surface Winds: Variable 3 to 7 MPH...northeast to east 15 to 20 ridges.

Free Winds: NE to E 15-20.
Tomorrow...Monday
Weather: Partly cloudy.
LAL: 1 CWR: zero
Maximum Temperatures: 50s and 60s, 40s and 50s higher elevations.
Minimum Humidities: 35 to 45%
Surface Winds: NE to E 5 to 15 MPH.
Free Air Winds: NE 15.
3-5 Day Outlook...Tuesday through Thursday.
Dry and warming. Highs warming into 65 to 75 range. Lows 20s and 30s warming to 30s and low 40s.

Cold and mostly overcast this morning. Fire inactive during the night. Afternoon turned clear and warmer. Fire activity increased although direct attack oppurtunity continued throughout the day (Loving 1988).

0920 hrs. Weather; Division A, across creek from DP 102; aspect east, slope 50%; DB 45F, WB 40F, RH 67, wind north 2-5, fine fuel moisture 11%. (Hann, Asst. FBA notes)

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	No data, Ranger Station abandoned.											
W. Glacier	No data											
S. Bear LO	--F	--%	--	0.00	70%	35%	7%	5%	8%	10%	65	87
S. Bear RS	--F	--%	--	0.00	100%	63%	5%	4%	11%	14%	49	73
H.Horse RS	--F	--%	--	0.00	90%	38%	7%	7%	11%	13%	51	97

1320 hrs. Weather at Logging Ridge, 4,465 feet msl; DB 53F, WB 44F, RH 51% wind northeast variable 0-2. Fire activity is starting to pickup. Sky is starting to clear. All divisions reporting active fire, spotting, torching, etc. (Hann, Asst. FBA notes)

1321 hrs. Weather at Division G J14, south of Quartz Creek, north of Logging Ridge, Aspect north, Slope 20%, 4,465 feet msl; DB 53F, WB 44F, RH 51%, wind northeast 0-2, fine fuel moisture 10%. Fire activity low, rate-of-spread 0.5 feet/minute, flame length 4 feet, spotting distance = 0 feet, Probability of Ignition 21-50%. (Hann, Asst. FBA notes)

1326 hrs. Sun came out for the first time today. (Hann, Asst. FBA notes)

1345 hrs. Some blue sky, but not much sun. Fire not real active. (Hann, Asst. FBA notes)

1500 hrs. Weather at Division G H15 south of Quartz Creek, north of Logging Ridge, Aspect north, Slope 5%, 3,900 feet msl; DB 57F, WB 47f, RH 49%, wind northwest 0-2, fine fuel moisture 10%. Fire activity moderate, rate-of-spread 5 feet/minute, flame length 4 feet, spotting distance 10 feet, Probability of Ignition 21-50%. (Hann, Asst. FBA notes)

1500 hrs. Some sunshine but mostly cloudy. (Hann, Asst. FBA notes)

1515 hrs. Gusts of wind from northeast. Areas of 4-5 foot flame length going into lower dead branches of spruce but then dropping and not crowning. (Hann, Asst. FBA notes)

1535 hrs. Weather at Division G H15 south of Quartz Creek, north of Logging Ridge, Aspect north, Slope 5%, 3,900 feet msl; DB 56F, WB 45F, RH 44%, wind west 0-2, fine fuel moisture 10%. Fire activity low, rate-of-spread 0 - 0.25 feet/minute, flame length 1 foot, spotting distance 3 feet, Probability of Ignition 21-50%. (Hann, Asst. FBA notes)

1530 hrs. Missoula Fire Weather Afternoon Forecast -

Discussion: Fairly strong high pressure building from north over area tonight and Monday as wet upper level low pressure exists area on its way to the southeast. Very cold air-humid night tonight with warming and drying on Monday and Tuesday. Rather strong east to west pressure gradient setting up over southern zones tonight and Monday for some winds yet in the south.

Zone 104:

Tonight...
Weather: Clearing over area.
LAL: 1 CWR: zero
Miminum Temperatures: 30s with teens and 20s high country.
Maximum Humidities: 70% and higher.
Surface Winds: NE to SE 4 to 8, 15 across ridges.5 ridges/upper
Free Winds: NE to SE 15.
Tomorrow...Monday.
Weather: Mostly sunny to partly cloudy.
LAL: 1 CWR: zero
Maximum Temperatures: 60s, 50s higher country.
Minimum Humidities: 25 to 35%
Surface Winds: Variable 2 to 8 MPH. NE to SE 15 ridges.
Free Winds: NE to SE 15.
Outlook for Tuesday...
Fair with highs 60s and 70s and light winds. Low humidity 20 to 30%.

1830 hrs. Weather at Division G I13 Quartz Ridge on trail, Aspect south, Slope 50%, Elevation 4,000 feet msl; DB 57F, WB 41F, RH 23%, wind northeast 2-4, fine fuel moisture 10%. Hot surface fire. (Hann, Asst. FBA notes)

Regional Weather: It was cloudy and cold with northerly winds and scattered precipitation across Montana during the night. Great Falls had cold rain and wet snow most of the night, Butte reported 2" of snow, as did Lookouts on the Kooteani National Forest. Rain with snow fell above 5,000' in upslope areas with some precipitation sloping over the mountains into Yellowstone National Park. However, no moisture was being received in West Yellowstone and Gardiner and by late morning only a little had fallen in Cooke City. By the end of the day most of Yellowstone had .5 to 2" of snow, and up to 4" on the higher peaks around Cooke City, the Beartooth pass, and Red Lodge. Most areas in northern Idaho only received light precipitation of a few hundreds of an inch. Low temperatures this morning were in the 30's and 40's in all but a few locations. Temperatures ranged from 32 at Great Falls to 47 at Miles City. During the afternoon rain, snow, and fog continued to be reported east of the divide. In northern Idaho and western Montana high pressure was again

beginning to rebuild. By the end of the day measurable precipitation had been received over most of the state except in the northeast and extreme southwest corners. Snow depths of 1 to 4" were measured at higher elevations. The first measurable precipitation was reported by Harve since the 5th of July. Afternoon temperatures did not warm up much. By 1800 hrs temperature extremes ranged from 37 degrees at West Yellowstone to 66 at Thompson Falls. Most afternoon temperatures in Yellowstone National Park were in the 30's and 40's. Northern Idaho warmed into the 60's, and further west in the coastal areas of Oregon and Washington temperatures were in the 80's. Frost and freezing temperatures were possible during the upcoming night (Bushey 1989).

September 12 (Julian Date 256)

Very cold this AM (low 20's) with a heavy frost. After sun up temperatures rose rapidly. Fire remained fairly inactive during the day and line burnout was successful in some areas. Some spotting still occurring on Division B (west of river) (Loving 1988).

Moderating weather with less wind, but a bit warmer and drier. (Red Bench Fire Review, Gary Rahm, and Rod Norum)

0600 hrs. Weather at camp; DB 23F, RH 97%, wind calm.

0830 hrs. Missoula Fire Weather Morning Forecast -

Discussion: High pressure continues to build over area as upper level low pressure which is now centered over Nevada-Arizona moves further south and weakens. Pressure gradient continues to relax setting up light wind day.

Zone 104:

Today...
Weather: Clear to partly cloudy.
LAL: 1 CWR: zero
Maximum Temperatures: 60s with some 70s, 50s higher country.
Minimum Humidities: 25 to 35%.
Surface Winds: Variable 2 to 6 MPH...15 at times ridges.
Free Winds: variable 10 to 15 MPH.

Tonight...
Weather: Mostly clear and frosty.
LAL: 1 CWR: zero
Mimumum Temperatures: Mostly 30s with teens and 20s high country.
Maximum Humidities: 80 to 100%, 60 to 70% slopes/ridges.
Surface Winds: Mostly light downslope, easterly 15 ridges.
Free Winds: Varaible 10 to 15.

Tomorrow...Tuesday.
Weather: Mostly sunny.
LAL: 1 CWR: zero
Maximum Temperatures: 70s with 50s and 60s high country.
Minimum Humidities: 15 to 25%.
Surface Winds: Variable 2 to 6 MPH, NE to SE 15 ridges.
Free Air Winds: NE to E 15.

3-5 Day Outlook...Wednesday through Friday...
Dry and cool nights and warm afternoons, chance of a few showers, wind and minor cooling Friday. Highs 70s with a few 80s cooling 60s and 70s

Friday. Lows 30s and 40s.

6-10 Day Outlook...Friday through Tuesday.

Above normal temperatures and mostly dry.

Smoke Dispersion Forecast....

Dispersion fair to poor northern zones, fair to good south today. Light transport winds north and southeast to east 15 south. Dispersion mostly poor tonight with light downslope winds and inversions over valleys. Dispersion fair to por on Tuesday.

0840 hrs. Weather at Division A across creek from DP102, Aspect east, Slope 50%; DB 35F, WB 33F, RH 83%, wind north 0-2, fine fuel moisture 11%. (Hann, Asst. FBA notes)

0950 hrs. Weather at Division F, ridge, elevation 3,750 feet msl, doghair lodgepole on both sides of open cat line; DB 34F, WB 31F, RH 69%, wind calm, in heavy inversion layer.

1006 hrs. First sunlight shines thru.

1120 hrs. Weather at T35N, R22W, section 16, elevation 4,500 feet msl, Aspect north, Slope 20%, 15-20 foot 2nd growth, partially closed; DB 47F, WB 41F RH 62%, wind north (upslope) 0-2 gusts to 4.

1122 hrs. Weather at Division F, southeast aspect, elevation 3,500 feet msl, high canopy lodgepole thicket; DB 45F, WB 38F, RH 55%, wind southeast 3-5.

1148 hrs. Weather at Division F start of cat line on Bowman Creek side of F, Aspect southeast, Slope 10%, Elevation 4,000 feet msl; DB 46F, WB 41F, RH 68%, wind calm, fine fuel moisture 10%. (Hann, Asst. FBA notes)

1250 hrs. Weather at Division F, Aspect southeast, Slope 20%, Elevation 4,500 feet msl; DB 52F, WB 44F, RH 55%, wind east / southeast 0-2, fine fuel moisture 10%. Fire activity low, rate-of-spread 0.1 to 0.0 feet per minute, flame length 0.5 feet, spotting distance 3 feet, Probability of Ignition 21-50%. (Hann, Asst. FBA notes)

1300 hrs. Weather at T35N, R22W, section 16, elevation 5,800 feet msl, Aspect north, from within a burned timber stand; DB 50F, WB 43F, RH 59%, wind north - northwest 0-2 gusts to 5 upslope.

1300 hrs. Weather at 4,500 feet msl; DB 52F, WB 44F, RH 55%, wind variable upslope southeast 0-2, fine fuel moisture 9%, Probability of Ignition 30%. Fire activity low.

1300 hrs. Weather at Division B, northwest corner southwest 1/4 of southeast 1/4 section 15, 5,800 feet msl; DB 58F, WB 47F, RH 46%, wind southwest 0-5. (William Yates, USFS)

1330 hrs. Weather at Division B, northwest corner southwest 1/4 of southeast 1/4 section 15, 5,800 feet msl; DB 58F, WB 46F, RH 41%, wind southwest 0-5. (William Yates USFS)

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	No data, Ranger Station abandoned.											
W. Glacier	61F	51%	9	0.00	121%	91%	8%	13%	18%	16%	30	40
S. Bear LO	No data											
S. Bear RS	60F	47%	1	0.00	137%	82%	8%	15%	21%	18%	23	24
H.Horse RS	59F	41%	2	0.00	100%	43%	8%	14%	16%	14%	38	36

1400 hrs. Weather at 4,300 feet msl; DB 56F, WB 46F, RH 45%, wind upslope southeast 0-3. Rate-of-spread 0.5 feet per minute, mostly burning jackpot down and dead fuel.

1400 hrs. Weather at Division F, aspect southeast, elevation 3,500 feet msl, high canopy lodgepole thicket; DB 60F, WB 46F, RH 35% wind southwest 2-3.

1400 hrs. Weather at Division F, ridge, elevation 3,750 feet msl, doghair lodgepole on both sides of open cat line; DB 58F, WB 47F, RH 42%, wind northwest at 4, inversion lifting.

1420 hrs. Weather at Division B, southeast 1/4 of southeast 1/4 of section 15, 6,000 feet msl; DB 58F, WB 46F, RH 41%, wind calm (top of Benchmark Mountain, east side). (William Yates USFS)

1500 hrs. Weather at Division B same as above; DB 58F, WB 46F, RH 41%, wind calm. (William Yates USFS)

1500 hrs. Weather at Division F, west end, Aspect southwest, Slope 10%, elevation 3,800 feet msl; DB 67F, WB 52F, RH 38%, wind east 0-2. (Hann, Asst. FBA notes)

1500 hrs. Weather at T35N, R22W, section 21, elevation 6,800 feet msl, Aspect north, partially closed stand of subalpine fir and lodgepole pine on a ridge; DB 57F, WB 46F, RH 45%, wind northeast 0-3 gusts to 7.

1530 hrs. Weather at Division B, southeast 1/4 of southeast 1/4 of section 15, 6,000 feet msl; DB 59F, WB 46F, RH 38%, wind calm. (William Yates USFS)

1530 hrs. Missoula Fire Weather Afternoon Forecast -

Discussion: High pressure will remain over the area next few days with warming and drying. Upper level low pressure will continue to circulate a little moisture at higher levels of the atmosphere into the southern edge of Montana. Main affects will be to keep humidity up a little in south.

Zone 104:

Tonight...

Weather: Mostly clear. Patchy fog few low areas. Frosty.
LAL: 1 CWR: zero
Miminum Temperatures: 20s and 30s.
Maximum Humidities: 60% to 90% with 45 to 55% slopes/ridges in Idaho zones and high elevations in 104 and 105.

Surface Winds: Mostly light downslope 0 to 6 MPH. Ridge winds NE to SE 5 to 10.

Tomorrow...Tuesday.

Weather: Mostly sunny.
LAL: 1 CWR: zero
Maximum Temperatures: 65 to 75 in Montana with higher mountain areas mostly 60s.
Minimum Humidities: 25 to 35%, 15 to 25% drier south slopes.
Surface Winds: Variable 2 to 8 MPH.
Free Winds: E to SE 15.

Outlook for Wednesday...

Warm and dry. Highs 70s, higher mountain areas 60 to 70.

Air Dispersion Forecast...

Tonight: Mostly poor with light downslope winds and valley inversions.
Tuesday: Dispersion fair to poor. Slow mixing through 6 to 8 tds feet.
Tuesday Night: Mostly poor.

1600 hrs. Crews on Division F report active fire behavior.

1600 hrs. Weather at Division F, Aspect south, 3,800 feet msl, partially closed, open grown Douglas-fir canopy; DB 67F, WB 49F, RH 22%, wind southwest at 5.

1600 hrs. Weather at Division F, Aspect southeast, elevation 3,500 feet msl, high canopy lodgepole thicket; DB 65F, WB 48F, RH 29%, wind southwest 2-5, gusts 8-10.

1620 hrs. Weather at Division B, southeast 1/4 southeast 1/4 of section 15, 6,000 feet msl; DB 59F, WB 46F, RH 38%, wind calm. (William Yates USFS)

1643 hrs. Weather, DB 69F, WB 53F, RH 33%, wind south at 9.

1700 hrs. Weather at Division B, southeast 1/4 southeast 1/4 of section 15, 6,000 feet msl; DB 59F, WB 46F, RH 38%, wind calm. (William Yates)

1700 hrs. Weather at T35N, R22W, section 15 (DP101), elevation 5,600 feet msl, Aspect northeast, open; DB 64F, WB 56F, RH 63%, calm.

1730 hrs. Weather at Division F, Aspect south, 3,800 feet msl, partially closed, open grown Douglas-fir canopy: DB 65F, WB 51f, RH 35%, wind southwest 0-5, gusts to 8.

1830 hrs. Weather at Division F, Aspect south, 3,800 feet msl, partially closed, open grown Douglas-fir canopy; DB 62F, WB 51F, RH 46%, wind southwest 0-5.

Regional Weather: Skies cleared over the northern portion of the Region during the night, elsewhere there were cloudy to partly cloudy skies. Snow flurries continued at Butte and light rain at Billings during the night. Several stations reported patchy fog. Wind conditions were light to less than 15 MPH. Precipitation had pretty much ended by about 0600 hrs. The Northern Rocky Mountains from the Seely Lake-Lincoln areas south through Anaconda and Butte received a very good wetting rain the previous 24 hours. Also parts of central and eastern Montana had good rains. Several stations in central Montana

reported total rainfall amounts in excess of 2", and a number with amounts of an inch or more. The largest amount was 2.38" at Shonkin. The western edge of Montana and northern Idaho only received very light, scattered showers. In Yellowstone National Park .5" to 2" of snow fell across the higher elevations. Water equivalent of this snow was generally .25" or less. Temperatures overnight were in the 30's and 40's at most stations with frost being common in many areas. At 0600 hrs temperatures ranged from 23 at West Yellowstone to 46 at Miles City. In Missoula 29 degrees tied the record cold for this date in September (previous record recorded in 1964)(Bushey 1989).

Long Range Forecast: The three to five day outlook was for dry, cool nights and warm afternoons. A chance of a few showers, wind and some minor cooling by the 16th. In six to ten days the outlook was for above normal temperatures and mostly dry west of the divide, and normal temperatures and precipitation east of the divide (Bushey 1989).

September 13 (Julian Date 257)

0600 hrs. Weather; DB 27F, WB 32F, 100%, wind calm, smoked in - temperature inversion.

Cold this AM but not as cold as yesterday. Deep inversion this AM not lifting until afternoon. Approximately 1930 hrs a minor slopover occurs on Division F (north flank inside the park). Near midnight the fire appears to be less active (Loving 1988).

0900 hrs. Missoula Fire Weather Morning Forecast -

Discussion: High pressure over us and to the north will keep most of our area dry and sunny for most of this week. At the end of the week, however, it appears another low pressure system will arrive to bring a chance of more showers.

Zone 104:

Today...
Weather: Sunny
LAL: 1 CWR: zero
Maximum Temperatures: Warmer...62-72.
Minimum Humidities: 20 to 30%.
Surface Winds: Easterly 5 to 10 MPH, otherwise terrain driven.
Free Winds: Easterly 15 MPH.

Tonight...
Weather: Fair, some areas of frost or fog.
LAL: 1 CWR: zero
Mimumum Temperatures: Lows 30 to 45.
Maximum Humidities: 75 -90%.
Surface Winds: Easterly 3-6 MPH exposed areas, otherwise calm to downslope 2-4 MPH.
Free Winds: Easterly 10 MPH.

Tomorrow...Wednesday.
Weather: Sunny and warmer.
LAL: 1 CWR: zero
Maximum Temperatures: 65 to 75.
Minimum Humidities: 20 to 25%

Surface Winds: Easterly 5 to 10 MPH.
Free Air Winds: SW to W 15.

3-5 Day Outlook...Thursday through Saturday.

Mostly sunny Thursday, increasing clouds Friday and Saturday for a chance of showers. Cooling to the mid 50s and 60s by Saturday. Lows mid 30s to mid 40. Winds becoming southwest.

6-10 Day Outlook...Sunday through Thursday.

Above to normal precipitation, below normal temperatures.

1000 hrs. Weather at Division F, 3,900 feet msl, Aspect southwest; DB 48f, WB 44F, RH 75%, wind soouthеast 2-4.

1000 hrs. Weather at Division G, southeast of DP 203, 4,200 feet msl, Aspect northwest, in moderate density standing timber, DB 47F, WB 43F, RH 74%, wind upslope northwest 0-1.

1045 hrs. Weather at Division B, southwest corner section 19, Hay Creek, 4,000 feet msl; DB 50F, WB 45F, RH 70%, wind northwest 0-3. (William Yates USFS)

1200 hrs. Weather at Division G below Quartz Ridge, 4,800 feet msl, aspect west, moderate density standing timber (Douglas-fir, larch, lodgepole pine mixture); DB 57F, WB 49F, RH 59%, wind upslope/calm.

1200 hrs. Weather at Division F, 3,900 feet msl, Aspect southwest; DB 57F, WB 46F, RH 45%, wind west to northwest 2-4.

1205 hrs. Weather at Division B, intersection of Spruce Creek Road and Section line 12/13, 4,080 feet msl; DB 59F, WB 48F, RH 47%, wind northwest 0-4. (William Yates USFS)

1230 hrs. Weather at 4,100 feet msl; DB 65F, WB 52F, RH 56%, wind upslope 0-3, 1-hr fuel moisture 9%, Probability of Ignition 30%.

1320 hrs. Weather at DP 107, 4,400 feet msl; DB 66F, WB 53F, RH 41%, wind upslope northeast 0-3 eye level, estimated at 5-6 at 20" level, 1-hr fuel moisture 8%, Probability of Ignition 40%.

1326 hrs. Division F requests water drops, increasing intensities reported.

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	No data, Ranger Station abandoned.											
W. Glacier	No data											
S. Bear LO		45%		0.00	97%	47%	8%	11%	17%	13%	40	40
S. Bear RS		28%		0.00	139%	84%	5%	10%	20%	18%	27	29
H.Horse RS		34%		0.00	101%	44%	6%	13%	16%	14%	39	39

1400 hrs. Weather at Division G, 4,800 feet msl, Aspect northwest, moderate density standing timber; DB 66F, WB 52F, RH 40%, winds upslope northwest 2-4.

1445 hrs. Weather at Division B, Cord. C-4, 5,100 feet msl; DB 70F, WB 59F, RH 51%, wind northeast 2-4, 1-hr fuel moisture 8%, Probability of Ignition 40%. Aspect southeast, fuels on Benchmark Mountain.

1500 hrs. Observed laddering, moderate torching. Wind is picking up, upslope northeast at 5 MPH, 65% slope.

1526 hrs. Open torching.

1545 hrs. Weather at 4,475 feet msl; DB 71F, WB 54F, RH 31%, wind northeast 4-5, 1-hr fuel moisture 7%, Probability of Ignition 50%.

1600 hrs. Weather at Division F, 3,900 feet msl, Aspect southwest; DB 73F, WB 53F, RH 27%, wind variable direction 5-6.

1600 hrs. Weather at Division G, Bowman Creek, 4,000 feet msl, creek bottom; DB 72F, WB 55F, RH 35%, wind calm.

1630 hrs. Torching and spotting, four spots across the line smoldering.

1645 hrs. Weather at DP205, 4,475 feet msl; DB 81F, WB 57F, RH 19%, wind upslope southwest 4-5 eye level, 8-10 at 20' level, 1-hr fuel moisture 4%, Probability of Ignition 70%. Fire is still running, estimated rate-of-spread 13 chains per hour, flame length 6-7'.

1748 hrs. Weather at DP 203, 4,450 feet msl; DB 72F, WB 53F, RH 28%, wind calm. Torching.

Fire activity all day moderate with some runs and spotting.

Hotter and drier, windier, more ominous fire behavior forecast.**NOTE** Northern easterly winds. (Red Bench Fire Review, Gary Rahm, and Rod Norum)

Night shift:--high RH, low temp. Low fire behavior--favorable for burnout until 2300. (Red Bench Fire Review, Gary Rahm, and Rod Norum)

Regional Weather: The low pressure system that had brought the moisture to the Region was now off over westcentral Utah. Clouds from the low were still over southern Montana this morning with some showers being reported in Monida, West Yellowstone, and Billings. The remaider of Montana and Idaho was under the influence of a large ridge of high pressure that extended north into Alberta. No precipitation was reported across Montana during the last 24 hours ending at 0600 hrs. Low temperatures during the morning were quite variable, with most locations in the mid to upper 30's, and some 40's along the Canadian border in eastern Montana. At 0600 hrs temperatures ranged from 30 degrees at Butte to 43 at Billings. During the afternoon most of Montana had sunny skies except for the south which was partly cloudy to cloudy with light rain showers in the southcentral and southwest mountainous portions of the Region. Winds were generally less than 15 MPH, with Livingston being the exception with winds 20 to 25 MPH out of the southeast. Smoke lowered visibility to 10 miles or less in the Kalispell vicinity. Afternoon temperatures remained mild ranging from 53 degrees at Billings to 88 at Thompson Falls (Bushey 1989).

September 14 (Julian Date 258)

0600 hrs. Weather; DB 31F, RH 97%, wind calm.

Cold again this AM although warmer than yesterday. Deep inversion again this morning. Fire inactive throughout the night (Loving 1988).

0900 hrs. Missoula Fire Weather Morning Forecast -

Discussion: The main weather feature affecting our area is high pressure in the Pacific Northwest. A low in southwest Wyoming is moving slowly northeast and some clouds associated with that are getting into southwest Montana. Thursday night another low pressure system will come out of the Gulf of Alaska and will likely bring us some more rain and snow.

Zone 104:

Today...
Weather: Sunny
LAL: 1 CWR: zero
Maximum Temperatures: 70s to 80s.
Minimum Humidities: 17 to 25%.
Surface Winds: Variable, mainly upslope 3-7 MPH. East to southeast across ridges, 5-10 MPH.
Free Winds: Southerly 7 MPH.

Tonight...
Weather: Fair.
LAL: 1 CWR: zero
Mimumum Temperatures: 30-45.
Maximum Humidities: Near 100% bottom areas, thermal belt conditions likely again with ridge recovery fair, max near 45%.
Surface Winds: Mainly downslope 0-4 MPH. Still east to southeast across ridges 3-8 MPH.
Free Winds: Southerly 7 MPH.

Outlook for Thursday.
Little change in general. Some high clouds moving in from the west in the afternoon mainly.

3-5 Day Outlook...Friday through Sunday.
Good chance of showers, snow in the mountains. Highs in the 70s Friday, cooling to be mainly in the 40s and 50s for the weekend.

Smoke Dispersion Forecast....
Becoming fair today most areas. Transport wnds light and easterly. Generally poor tonight with inversions developing and light winds. Little change Thursday from today, except transport winds more southerly.

1050 hrs. Division B reports torching and running.

1100 hrs. Weather; DB 56F, WB 47F, RH 49%, wind calm, 1-hr fuel moisture 8%, Probability of Ignition 40%.

1100 hrs. Weather at Division F, north side, 4,200 feet msl, Aspect north, ridgetop, open lodgepole pine canopy; DB 54F, WB 45F, RH 52%, wind northwest 2-3, sightly gusty.

1200 hrs. Weather at Division F, north side, 4,200 feet msl, Aspect north, ridgetop, open lodgepole pine canopy; DB 60F, WB 49F, RH 47%, wind southeast 3-6, moderately gusty.

1200 hrs. Weather at Division B; DB 61F, WB 50F, RH 47%, wind upslope east 3-4, 1-hr fuel moisture 8%, Probability of Ignition 40%.

1215 hrs. Weather at Division F, 3,800 feet msl, level bench, semi-open lodgepole pine stand; DB 62F, WB 50F, RH 41%, wind calm, slight breeze from north.

1245 hrs. Weather at 4,500 feet msl; DB 61F, WB 52F, RH 53%, wind northwest 2-3, 1-hr fuel moisture 8%, Probability of Ignition 40%.

1300 hrs. Weather at Division F, north side, 4,200 feet msl, Aspect north, ridgetop, open lodgepole pine canopy; DB 68F, WB 52F, RH 37%, wind southwest 3-6, moderately gusty.

1326 hrs. Weather; DB 72F, WB 55F, RH 32%, wind south 6-7 eye level, 10-12 at 20 feet level, 1-hr fuel moisture 6%, Probability of Ignition 50%, zero shading.

1330 hrs. Weather at Division F, 3,800 feet msl, level bench, semi-open lodgepole pine stand; DB 68F, WB 52F, RH 30%, wind calm, slight breeze from north.

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	No data, Ranger Station abandoned.											
W. Glacier	No data											
S. Bear LO	65F	35%	3	0.00	96%	47%	6%	9%	14%	13%	45	42
S. Bear RS	76F	26%	4	0.00	140%	85%	5%	8%	18%	18%	29	33
H.Horse RS	72F	34%	6	0.00	103%	46%	6%	11%	16%	14%	40	45

1400; fire activity so far has been moderate.

1400 hrs. Weather at Division F, 3,850 feet msl, level bench, open Douglas-fir / spruce forest with standing dead lodgepole pine; DB 68F, WB 53F, RH 34%, wind northwest 0-5, slightly gusty.

1500 hrs. Missoula Fire Weather Afternoon Forecast -

Discussion: High pressure will hold over the area for another 24 hours. Southwesterly flow will develop on Friday with a Pacific front moving into the Region during the day. Moisture appears limited at first, but gusty winds almost assured. Low pressure aloft will move slowly into the Northwest over the weekend and bring some moisture.

All Zones:

Tonight...

Weather: Fair.

LAL: 1 CWR: zero
Miminum Temperatures: 35-45, Locally in the 20s higher mountain valleys.
Maximum Humidities: Near 100% valley bottoms, 50-70% slopes and ridges.
Surface Winds: Mostly light downslope 3 to 5 MPH.
Tomorrow...Thursday.
Weather: Fair.
LAL: 1 CWR: zero
Maximum Temperatures: 70-80
Minimum Humidities: 20 to 30%.
Surface Winds: Variable, mainly upslope 4-8 MPH.
Free Winds: W 10 MPH.
Outlook for Friday...
Increasing clouds, especially western zones. Chance of a few showers on Friday afternoon over the Idaho panhandle. Temperatures cooling 5 degrees and humidities up 5%.
Air Dispersion Forecast...
Tonight: Mixing becoming poor after 10 PM. Mixing limited to less than 1000 ft above ground level. Mixing winds light easterly.
Thursday: Mixing becoming good by midday. Mixing winds southwest 10 MPH.
Mixing unlimited afternoon.

1500 hrs. Weather at Division F, north side, 4,200 feet msl, Aspect north, ridgetop, open lodgepole pine canopy; DB 74F, WB 53F, RH 27%, wind northwest 6-8, moderately gusty.

1520 hrs. Weather; DB 70F, WB 54F, RH 30%, wind southeast 2-3, 1-hr fuel moisture 7%.

1520 hrs. Weather at Division F, 4,300 feet msl, Aspect south, partial open canopy; DB 75F, WB 55F, RH 29%, wind southwest 0-5 gusts to 8, moderately gusty, wind greater above canopy.

1600 hrs. Weather at Division F, 3,850 feet msl, level bench, open Douglas-fir / lodgepole pine forest with standing dead lodgepole pine; DB 72F, WB 55F, RH 32%, wind west 0-5, moderately gusty.

1600 hrs. Weather at Division F, north side, 4,200 feet msl, Aspect north, ridgetop, open lodgepole pine canopy; DB 78F, WB 55F, RH 25%, wind southeast 6-8, moderately gusty.

1634; Division G reports problems.

1640 hrs. Weather at Division F, 4,300 feet msl, Aspect south, partial open canopy; DB 75F, WB 55F, RH 29%, wind southwest 0-5 gust to 10 slightly gusty, periods of calm.

1645 hrs. Weather at Division G; DB 74F, WB 50F, RH 15%, wind north north-east at 4, 1-hr fuel moisture 5%. Fire running with some spotting.

Moderate weather forecast, moderate fire behavior. (Red Bench Fire Review, Gary Rahm, and Rod Norum)

Regional Weather: Variable cloudiness and scattered showers occurred along the southern border of the Region during the night. Skies were fair and winds light over the rest of the area. Low temperatures in Montana this morning were mostly in the 40's and low 50's, ranging from 32 degrees at Drummond to 52 at Miles City. During the afternoon the southern border remained cloudy and cool while the rest of the Region had sunny skies and light winds. Afternoon temperatures were in the upper 60's and 70's, with highs ranging from 61 at West Yellowstone to 95 at Thompson Falls. The Northwest also had sunny skies with temperatures ranging from 60's along the west coast and southern Idaho, and into the 80's across northern Idaho (Bushey 1989).

September 15 (Julian Date 259)

0600 hrs. Weather; DB 31, RH 92%, wind calm.

0900 hrs. Missoula Fire Weather Morning Forecast -

Discussion: High pressure will weaken over area today with approaching frontal system and upper level trough of low pressure from the Pacific. Frontal system moving into Northern Idaho tonight and through Montana Friday. The low pressure aloft will move over the Northwest this weekend and bring cooling and some moisture.

Zone 104:

Today...
Weather: Mostly sunny with sonme high clouds.
LAL: 1 CWR: zero
Maximum Temperatures: 75 to 85.
Minimum Humidities: 15 to 25%.
Surface Winds: Becoming southwest to west 5 to 15 with 10 to 20 exposed areas.
Free Winds: southwest 15 to 20.

Tonight...
Weather: Partly cloudy. Slight chance of showers north.
LAL: 1 CWR: zero
Mimumum Temperatures: 40s and 50s.
Maximum Humidities: 50 to 80%.
Surface Winds: southwest to northwest 5 to 15 with 15 to 25 higher exposed areas.
Free Winds: southwest to west 20.

Tomorrow...Friday.
Weather: Partly cloudy to cloudy. Chance few showers.
LAL: 1 CWR: 10 to 20 %
Maximum Temperatures: 60s to 70s.
Minimum Humidities: 25 to 35%.
Surface Winds: southwest to northwest 10 to 20 with 15 to 30 high exposed areas.
Free Air Winds: west to northwest 25.

3-5 Day Outlook...Saturday through Monday.
Scattered showers with some areas of light rain or snow Sunday, mainly Montana zones. Cooler and windy at times. Highs 50s and 60s with 40s high areas. Lows 30s and 40s.

6-10 Day Outlook...Tuesday Septmber 20 through Saturday Septmber 24...

Temps: below normal Precip: near normal

1100 hrs. Weather; DB 61F, WB 51F, RH 54%, wind east 4-5, 1-hr fuel moisture 8%.

1100 hrs. Weather at Division A, 5,600 feet msl, Aspect north, open clearcut and road; DB 61F, WB 52F, RH 57%, wind west 5 gusts to 9.

1130 hrs. Weather at Division F, 4,400 feet msl, Aspect southwest, semi-open subalpine fir / lodgepole pine canopy on saddle of ridge; DB 63F, WB 50F, RH 42%, wind south 2-3.

1230 hrs. Weather; DB 67F, WB 51F, RH 29%, wind west 8-10, 1-hr fuel moisture 8%. Torching in Division B.

1300 hrs. Weather at Division A, DP 106, 4,100 feet msl, Aspect north, open near creek bottom; DB 74F, WB 52F, RH 22%, wind southwest 4 gusts to 8.

1300 hrs. Weather at Division F; DB 72F, WB 52F, RH 25%. One large spot at C-9 Division F.

1300 hrs. Weather at Division F, 4,400 feet msl, Aspect southwest, semi-open subalpine fir / lodgepole pine canopy on saddle of ridge; DB 72 , WB 52F, RH 22%, wind west 4-5 gusts to 8, moderately gusty. Winds greater above the canopy.

1300 hrs. Weather at NP viewpoint; DB 75F, WB 55F, RH 25%, wind southeast upslope 2-4, 1-hr fuel moisture 8%.

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	No data, Ranger Station abandoned.											
W. Glacier	No data											
S. Bear LO	62F	28%	9	0.00	95	45%	6%	8%	16%	15%	39	39
S. Bear RS	80F	17%	5	0.00	140%	85%	4%	7%	17%	18%	30	37
H.Horse RS	75F	30%	3	0.00	104%	46%	6%	11%	15%	14%	40	40

1400 hrs. Weather at NP viewpoint; DB 73F, WB 53F, RH 24%, wind variable northwest 6-8. Extreme fire behavior at Division G. Division F is having numerous spots.

Long range spotting was reported to be 1/2 to 3/4's of a mile. (Pat Velasco, Incident FBA, Fire Behavior Forecast No. 18-Revised for the Night Shift)

1400 hrs. Weather at Division F, 4,400 feet msl, southwest aspect, open canopy due to dead lodgepole pine on a level bench; DB 75F, WB 53F, RH 23%, wind west 3-8 gusts to 24, moderately gusty, wind speed greater above tree tops.

1438 hrs. Extreme fire behavior in Division G, Quartz Ridge.

1500 hrs. Weather at Division A, 5,200 feet msl, Aspect northwest, in a clearcut; DB 70F, WB 52F, RH 30%, wind variable direction west 7 gusts to 10.

1500 hrs. Weather at Division F, 4,400 feet msl, Aspect southwest, semi-open subalpine fir / lodgepole pine canopy on saddle of ridge; DB 79F, WB 54F, RH 19%, wind southeast 4-5, very gusty, estimated above canopy 14-21 MPH.

1530 hrs. Missoula Fire Weather Afternoon Forecast -

Red Flag Watch for zones 103...107...108...106 east of Divide for strong gusty west to southwest winds developing Friday. Other zones will see these winds develop, but feel the situation is not quite to Red Flag with the cooler temps and higher humidities expected.
Discussion: A developing low pressure system will head our way down the Canadian coast tonight and Friday. The first front will be rather weak, but some showers are expected anyway. A break is likely Saturday, then another impluse will come in late Saturday for more precipitation Sunday. This low will move east next week with a cool northerly flow following it.

Zone 104:

Tonight...
Weather: Fair, some high clouds late tonight.
LAL: 1 CWR: near zero
Miminum Temperatures: 35-45.
Maximum Humidities: Recovery bottom areas near 100%, otherwise recovery fair 50-60%.
Surface Winds: Mainly southerly 2-8 MPH exposed areas, otherwise downslope 1-4 MPH or calm.
Tomorrow...Friday.
Weather: Increasing clouds with a chance of showers.
LAL: 1 CWR: 10%
Maximum Temperatures: Much cooler 62-72.
Minimum Humidities: 30 to 40%.
Surface Winds: Southwest to west gusty and increasing, becoming 10 to 20 MPH with gusts to 25 across the ridges.
Free Winds: Southwest 25 MPH.
Outlook for Saturday...
Mostly cloudy. Chance of showers greatest late afternoon. Temps much cooler, down 12-18 degrees, humidity up 15-20%.
3 to 5 Day Outlook...Sunday through Tuesday.
Showers of rain or snow Sunday, decreasing into Monday. Partly cloudy Tuesday. Cool Sunday and Monday, highs in the 50s to mid 60s mainly. Warmer Tuesday. Over night lows 30s and 40s. Winds west becoming northwest Tuesday.

1615 hrs. Weather at Division F, 4,400 feet msl, Aspect southwest, semi-open subalpine fir / lodgepole pine canopy on saddle of ridge; DB 78F, WB 53F, RH 18%, wind southwest 5-8, very gusty, wind blowing hard through canopy with a swirling action.

1650 hrs. Weather; DB 72F, WB 49F, RH 18%, wind northwest 10 with gusts to 25, 1-hr fuel moisture 4%, Probability of Ignition 70%.

1715 hrs. Weather at Division F, 4,400 feet msl, southwest aspect, open canopy due to dead lodgepole pine on a level bench; DB 74F, WB 52F, RH 21%, wind southwest 5-8 gusts to 19 with greater speeds above the canopy.

1729 hrs. More extreme fire behavior. Most of Division F is being lost. Flame lengths 50+ feet.

1745 hrs. Weather; DB 71F, WB 50F, RH 20%, wind west 8-10.

1230 - 2000; Very active fire behavior Division F & G. Many spots, torching and runs until about 1800 when many crews had to go to safety zones. Crews worked very hard until they could no longer catch the spots. Observed fire behavior for blowup conditions in Division G, rate-of-spread estimated at 6 miles in 7 hours on Quartz Ridge, approximately 70 to 80 chains per hour. Strong westerly winds and fire behavior contributed to excessive rate-of-spread. Occular estimate of fuel loading lodgepole pine, subalpine fir and some spruce; 25 to 30 tons/acre. Seven hours of extreme, high fire behavior.

Cold (near 30) again this morning. Inversion present but not as much smoke and fog visible. Inversion lifted early today and winds picked up about noon (earlier than expected). Spotting in Divisionision F at 1400 hrs. Division F was pushed hard by the fire and severe long range spotting occurred. About five miles of line was lost. (Red Bench Fire Narrative, Gary Loving, Deputy Planning southeastction Chief)

Weather moderate during the day, with cold front coming in the evening. Note: this blew out the north end of Division F. Fire behavior moderate during the day, but increasinly active as evening approaches. (Red Bench Fire Review, Gary Rahm, and Rod Norum)

Regional Weather: Morning skies were mostly clear across the Region except the southern half of Montana and along the Montana-Dakotas border. Winds were generally 15 MPH or less, with stations in western Montana reporting mostly 10 MPH or less. Overnight low temperatures ranged from the 30's in the southwest to the mid-50's in the east. At 0600 hrs Butte was the coolest spot with 34, the warmest was 56 at Great Falls. By the afternoon sunny skies and warm temperatures were across the Region. Afternoon temperatures rose to the 70's and lower 80's, ranging from 66 at West Yellowstone to 90 at Thompson Falls. Strongest winds were in the Livingston area with gusts over 30 MPH, other areas reported 10 to 20 MPH gusts (Bushey 1989).

September 16 (Julian Date 260)

0600 hrs. Weather; DB 43F, RH 66%, wind north at 4, 100% overcast.

0900 hrs. Missoula Fire Weather Morning Forecast - ...Red Flag Today, poor humidity recovery slopes/ridges overnight followed by gusty winds today... Discussion: Pacific frontal system moving through area this morning. Upper level trough of low pressure now over Oregon and Washington. Most moisture still kept north of Canadian border. This should slip southward Saturday as upper wind flow pattern becomes more northerly. Good cooling with this feature.

Zone 104:

Today...

Weather: Mostly cloudy. Few light showers.
LAL: 1 CWR: 10%
Maximum Temperatures: 65 to 75, 55 to 65 higher elevations.
Minimum Humidities: 15 to 25%, becomng 25 to 35% afternoon.
Surface Winds: southwest to west 10 to 15 MPH with 15 to 25 gusty more exposed
areas.
Free Winds: Southwest 25.

Tonight...

Weather: Mostly cloudy. Few rain/snow showers.
LAL: 1 CWR: 10 to 20%
Mimumum Temperatures: 30s to 40s.
Maximum Humidities: 60 to 70%.
Surface Winds: West to northwest 5 to 15 with 15 to 30 gusty more exposed areas.
Free Winds: West 25.

Tomorrow...Saturday.

Weather: Cloudy. Scattered showers. Areas of light rain or snow developing high country.
LAL: 1 CWR: 30 to 40%
Maximum Temperatures: 70 to 85
Minimum Humidities: 40 to 50%.
Surface Winds: West to northwest 5 to 15 with 15 to 25 gusty exposed areas.
Free Air Winds: West to Northwest 25.

3-5 Day Outlook...Sunday through Tuesday.

Cool and breezy. Occasional light rain or snow likely Montana zones and few showers in Idaho. Slow warming and drying Monday and Tuesday. High 50s and 60s south and 40s and 50s north warming to 60s and 70s by Tuesday. Lows 30s and 40s, 20s high country.

Smoke Dispersion Forecast....

Mostly good this afternoon through Saturday with good transport winds most areas.

0915 hrs. Weather at Division B DP 111, 5,680 feet msl, Aspect north, on open road; DB 52F, WB 40F, RH 30%, wind southwest 4-8, slightly gusty.

0945 hrs. Division F reporting torching.

1000 hrs. Weather at Division F, 4,200 feet msl, Aspect west, open canopy along catline; DB 56F, WB 44F, RH 39%, wind west 0-2 upslope breeze.

1100 hrs. Weather at Division F, 4,200 feet msl, west aspect, open canopy along catline; DB 63F, WB 49F, RH 38%, wind west 0-2.

1100 hrs. Weather at Division F, 4,300 feet msl, Aspect southwest, open canopy of lodgepole pine / subalpine fir on a ridge saddle; DB 63F, WB 46F, RH 27%, wind southeast 2-3, slightly gusty. Fire starting to run through canopy.

1100 hrs. Weather at Division F, 4,000 feet msl; DB 56F, WB 46F, RH 44%, wind upslope northwest at 2, partly cloudy, 1-hr fuel moisture 10%.

1100 hrs. Weather at Division G, T34N, R20W, section 5, Logging Ridge, 3,840 feet msl, Aspect west, 40% stand density of spruce and subalpine fir; DB 62F, WB 49F, RH 39%, wind southwest 2-4.

1130 hrs. Weather at Division B, DP 110, 3,720 feet msl, Aspect south, on open road; DB 50F, WB 67F, RH 26%, wind southwest 2-9, slightly gusty.

1143 hrs. Weather at Division F, 4,000 feet msl; DB 63F, WB 47F, RH 27%, 1-hr fuel moisture 8%.

1158 hrs. Fire becoming active in Division F.

1230 hrs. Weather at Division F, 4,200 feet msl, Aspect west, open canopy along catline; DB 64F, WB 48F, RH 31%, wind west 2 upslope breeze.

1230 hrs. Weather at Division G, T34N, R20W, section 5, Logging Ridge, 3,840 feet msl, Aspect west, 40% stand desnity of spruce and subalpine fir; DB 65F, WB 50f, RH 34%, wind southwest 4-8 gusts 12-15.

1234 hrs. Weather at Division F, 4,000 feet msl; DB 62F, WB 47F, RH 28%, wind upslope northeast 4-5, 1-hr fuel moisture 8%. Open torching visible in Division F which is reporting southwest winds.

1300 hrs. Wind is picking up, open torching.

1300 hrs. Weather at Division F, 4,300 feet msl, Aspect southwest, open canopy of lodgepole pine / subalpine fir on a ridge saddle; DB 68F, WB 49f, RH 25%, wind southwest 4-6 gust of 6-10 MPH.

1307 hrs. First spot. Wind on fire is from the west.

1315 hrs. Weather at Division F, 4,000 feet msl; DB 67F, WB 47F, RH 28%, wind W 5-8, 1-hr fuel moisture 8%.

1322 hrs. Division F reporting spotting and torching.

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	No data, Ranger Station abandoned.											
W. Glacier	No data											
S. Bear LO	52F	38%	7	0.00	106%	74%	5%	5%	15%	14%	42	50
S. Bear RS	70F	23%	10	0.00	139%	83%	5%	7%	17%	18%	31	45
H.Horse RS	67F	26%	11	0.00	102%	44%	6%	10%	10%	14%	43	59

1400 hrs. Weather at Division F, 4,300 feet msl, Aspect southwest, open canopy of lodgepole pine / subalpine fir on a ridge saddle; DB 69F, WB 49F, RH 23%, wind southwest 4-6, moderately gusty. Fire is traveling hard through canopy.

1400 hrs. Weather at Division F, 4,200 feet msl, Aspect west, open canopy along catline; DB 68F, WB 50F, RH 28%, wind variable north-northwest at 7 gusts to 10.

1400 hrs. Weather at Division G, T34N, R20W, section 4, Logging Ridge, 4,500 feet msl, Aspect west, partially open stand of larch / Douglas-fir on a ridgetop; DB 61F, WB 48F, RH 40%, wind southwest 15-20 gusts to 30.

1430 hrs. Weather at Division G, T34N, R20W, section 4, Logging Ridge, 4,500 feet msl, Aspect west, partially open stand of larch / Douglas-fir on a ridgetop; DB 63F, WB 48F, RH 34%, wind southwest 15-20 gusts to 30.

1430 hrs. Weather at Division B, DP 104, on the river; DB 52F, WB 70F, RH 26, wind south 2-6, slightly gusty.

1500 hrs. Weather at Division F, 4,300 feet msl, Aspect southwest, open canopy of lodgepole pine / subalpine fir on a ridge saddle; DB 62F, WB 42F, RH 15%, wind northeast 4-6, moderately gusty. Fire is traveling hard through canopy.

1530 hrs. Weather at Division G, T34N, R20W, section 4, Logging Ridge, 4,500 feet msl, Aspect west, partially open stand of larch / Douglas-fir on a ridgetop; DB 65F, WB 49FRH 32%, wind southwest 15-20 gusts to 30.

1600 hrs. Weather at Division F, 4,300 feet msl, Aspect southwest, open canopy of lodgepole pine / subalpine fir on a ridge saddle; DB 64F, WB 42F, RH 11%, wind southwest 5-9, very gusty. Fire is traveling hard through canopy.

1600 hrs. Weather at Division F, 4,200 feet msl, Aspect west, open canopy along catline; DB 67F, WB 49F, RH 27%, wind southwest 8 gusts to 12.

1630 hrs. Weather at Division F, 4,000 feet msl; DB 57F, WB 47F, RH 45%, wind northwest 6-8 gusts to 10, 1-hr fuel moisture 8%.

1700 hrs. Weather at Division F, 4,300 feet msl, Aspect southwest, open canopy of lodgepole pine / subalpine fir on a ridge saddle; DB 63F, WB 43F, RH 16%, wind southwest 5-9, moderately gusty. Fire is traveling hard through canopy.

Notes on fine fuel moisture and observed behavior; as the day progressed 7-6% experienced high fire behavior, 5-8% extreme, 9% high, 10% occasional torching.

Todays fire behavior on Division A, B & C was insiginificant. Activity was limited to isolated torching, primary activity was creeping. Branch II, Division F was very active with spotting and torching begining about 0900 hrs in the northwest corner of Akokala canyon. Became very difficult to contain with either hand crews, tractors or slurry. At about 1545 hrs the corner blewout and began crowning and spotting. This activity continued until 2000 hrs. Fire along the rest of the line was held. Division G was very active and the fire advanced over 2 miles on Quartz Ridge. No problems controling fire on the line. A spot fire was quickly contained and controled at about 1/4 acre in Cummings Meadows between sections 4 & 5.

Not as cold this AM. Wind calm with some high, thin clouds. Fire inactive. Fire became active about 1500 hrs in Division F again and spotted across the line into a boggy area. Air support unable to handle a major run up Akokala Creek. (Red Bench Fire Narrative, Gary Loving, Deputy Planning southeastction Chief)

Weather; strong trough approaching, atmosphere unstable--possible precipitaion, strong and shifting winds as trough passes. fire behavior expected to be extreme with strong west winds early in the day; intense fire and high rates of spread; long range spotting. Fire blew out in three spots along northern most and northeast flanks. Now using Bowman Lake Road as backup line. Dozers can't work in boggy areas around northeast perimeter without getting stuck and causing notable resource damage. (Red Bench Fire Review, Gary Rahm, and Rod Norum)

Regional Weather: Skies were mostly clear during the night, however by daybreak clouds associated with a dry Pacific weather front were moving over western Montana. Winds across the Region were generally less than 15 MPH, except for Billings which reported morning gusts of 20 MPH at times. Overnight low temperatures ranged from the mid-30's in the southwest to the mid-50's in the southcentral, West Yellowstone was the coolest at 33 and Billings the warmest at 56. By late afternoon the western half of the Region was under mostly cloudy skies, scattered showers and thunderstorms. Lightning started at 1312 hrs north of Helena and progressed to the northeast across Great Falls, Harve, and Harlem. Separate thunderstorm cells developed in the Choteau / Conrad areas along the eastern Rocky Mountain front, and over the Charles Russell National Wildlife Refuge and the Musselshell River in eastern Montana. Between 1312 hrs and 0503 hrs on the 17th there were 865 lightning strikes. The east half of the Region remained partly cloudy. Afternoon temperatures were 75 to 85 in the eastern half of Montana, 60's and low 70's elsewhere. Several areas reported 10 to 25 MPH winds. Only Great Falls had measurable precipitation by 1800 hrs, more rain fell during the night at Great Falls and also at Glasgow. Other locations had traces (Bushey 1989).

September 17 (Julian Date 261)

0600 hrs. Weather; DB 41F, RH 67%, wind northwest at 4, overcast.

1030 hrs. Snowing and raining.

1125 hrs. Snow at 3,800 feet msl level.

1140 hrs. Weather; DB 34F, RH 100%, wind calm, snowing.

1208 hrs. Snow is accumulating and sticking to the trees at the 4,200 feet msl level.

1249 hrs. 0.11 inch of rain at Polebridge Ranger Station.

1330 hrs. Moisture is penatrating 1/8 to 1/4 inch in to fuels at DP 204 and DP 205.

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	No data, Ranger Station abandoned.											
W. Glacier	No data											
S. Bear LO	26F	100%	10	0.24	99%	46%	27%	25%	14%	14%	0	0
S. Bear RS	40F	92%	2	0.30	139%	83%	23%	25%	18%	18%	0	0
H.Horse RS	41F	85%	0	0.40	106%	47%	21%	28%	16%	14%	0	0

1400 hrs. Weather at DP 205; DB 40F, WB 40F, RH 100%, wind calm.

Cloudy and cool this AM. Light rain began falling about 0730 hrs and continued hard throughout the day and at dark the trees are frosted several hundred feet above the camp. At 1900 hrs there is 4 inches of snow at Drop Point 101 and 0.4 inches of rain has fallen in camp. Rain stopped during the night, still cloudy and showers predicted. Very cold tonight. (Red Bench Fire Narrative, Gary Loving, Deputy Planning southeastction Chief)

Weather; colder,with unstable atmosphere, chance of precipitation up, west wind 15-20 with gusts. Fire behavior moderate to low in response to precipitation. (Red Bench Fire Review, Gary Rahm, and Rod Norum)

Today was a rain and snow day. 0.36" by 1800 hrs and 3 inches of snow at the 4,300 feet msl level. Crews all went out as scheduled but were brought back due to the bad weather. No major fire activity, only smoldering. (Pat Velasco, Incident FBA)

Regional Weather: Skies were mostly cloudy across the region last night as a cold front moved through accompanied by scattered showers, thundershowers and gusty winds. Winds were generally 15 MPH or less across Montana during the night. As the front passed Billings reported gusts up to 45 MPH were reported. At 0600 hrs low morning temperatures ranged from the mid-30's in the southwest portion of the Region to the mid-50's in the southeast. Butte was the coldest spot at 34 degrees, Broadus was the opposite extreme at 54 (Bushey 1989).

September 18 (Julian Date 262)

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	No data, Ranger Station abandoned.											
W. Glacier	No data											
S. Bear LO	26F	90%	2	0.26	104%	48%	22%	25%	19%	14%	23	24
S. Bear RS	45F	73%	3	0.24	141%	84%	16%	25%	20%	18%	17	20
H.Horse RS	49F	52%	8	0.51	112%	49%	12%	28%	18%	15%	26	36

Weather cold and foggy this morning. Fire remained quiet throughout the day and night. (Red Bench Fire Narrative, Gary Loving, Deputy Planning southeastction Chief)

Essential end of fire. (Red Bench Fire Review, Gary Rahm, and Rod Norum)

Regional Weather: A strong rain storm contained to move across the Region for the second day, bringing snow, rain, and unseasonably cool temperatures. Virtually all of Montana had received significant amounts of precipitation. The heaviest precipitation today shifted into the eastern half of the Region. There were scattered heavy thunderstorms in southeast and extreme eastern Montana. By afternoon it was snowing heavily in Great Falls (7" by noon) and in Lewistown, and a mixture of snow and rain at several other locations. Several RAWS units in the central part of Montana recorded .33" to .75"'s of rain in a 6 hour period. West of Havre to Great Falls to Butte the line of rain and snow ended. In the northwestern portion of the Region the skies were clearing and partly sunny. Afternoon temperatures were in the lower 50's west of the divide and east along the hi-line to Havre, elsewhere only in the 35 to 45 degree range. Winds of 15 to 30 MPH were common in the eastern portion of the Region (Bushey 1989).

September 19 (Julian Date 263)

0600 hrs. The fire is cloudy with light drizzle falling. At 0930 day shift is canceled and crews moved to dry shelter. (Red Bench Fire Narrative, Gary Loving, Deputy Planning southeastction Chief)

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	No data, Ranger Station abandoned.											
W. Glacier	No data											
S. Bear LO	No data											
S. Bear RS	42F	93%	2	0.28	150%	89%	23%	25%	21%	19%	0	0
H.Horse RS	44F	93%	3	0.41	112%	54%	24%	28%	20%	16%	0	0

Estimated time of containment now September 21. (Red Bench Fire Review, Gary Rahm, and Rod Norum)

Regional Weather: Low 0600 hrs temperatures ranged from the upper 20's to mid-30's across most of the Region; northern Idaho and southwestern Montana had lows in the upper 40's. West Yellowstone had the coolest temperature at 20 degrees, Dillon the warmest at 49. Most of western Montana and northern Idaho remained cloudy during the day as an upper level low moved into the western portion of the Region. Rain from this new system had been falling in some northwestern areas nearly all day. The eastside of the divide remained partly cloudy. Winds were generally light across Montana. Afternoon high temperatures were mostly in the 50's, with Broadus the warmest spot at 61. Most of the snow which had fallen along the east slopes of the Rockies and in central Montana yesterday had melted by noon (Bushey 1989).

September 20 (Julian Date 264)

Demobilization.

1400 hrs. **NFDRS Fire Weather, Fuel Moisture and Fire Danger Calculations**

	Dry Bulb Temp	RH	Wind Speed	PPT	Woody Moist	Herb Moist	1-Hr Moist	10-Hr Moist	100-Hr Moist	1000-Hr Moist	ERC	BI
Polebridge	No data, Ranger Station abandoned.											
W. Glacier	No data											
S. Bear LO	No data											
S. Bear RS	52F	60%	1	0.05	154%	91%	14%	25%	21%	20%	19	22
H.Horse RS	51F	64%	0	0.77	135%	61%	16%	37%	23%	18%	13	17

Regional Weather: Mostly cloudy skies across the Region during the night, with light rain at Butte, Kalispell, and Helena. Winds at most stations were light and less than 10 MPH. Glasgow was the exception with winds southeasterly 10 to 20 MPH. Most morning low temperatures were slightly warmer than the preceding days, up in the 40's. Coldest location was West Yellowstone at 35 degrees, warmest was Livingston at 46. As the day progressed a steady rain continued to fall in a band from central to southwest Montana. elsewhere it was partly cloudy. Afternoon temperatures ranged from the mid-40's through the 50's (Bushey 1989).

September 28 (Julian Date 273)

Fire was contained.

October 23 (Julian Date 297)

Fire still not listed as controlled.

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1988 RED BENCH FIRE

C. Bushey

2100 Hrs 9/16
0015 Hrs 9/15
0200 Hrs 9/10
2130 Hrs 9/9
0830 Hrs 9/8
1835 Hrs
2030 Hrs
1635 Hrs 9/6
Origin
0630 Hrs 9/7
0830 Hrs 9/8
0200 Hrs 9/10
2130 Hrs 9/9
2300 Hrs
0630 Hrs 9/7
1400 Hrs
1600 Hrs
1300 Hrs
1900 Hrs
2330 Hrs
0830 Hrs 9/8
2130 Hrs 9/9
0830 Hrs 9/8
2100 Hrs 9/16
0015 Hrs 9/14
0015 Hrs 9/14
0435 Hrs 9/15
0200 Hrs 9/10
2130 Hrs 9/9
2100 Hrs 9/16